

Appendix A: Project Facilities

Environmental Health Laboratory, California Department of Health Services

The Microscopy Unit of the Outdoor Air Quality Group was equipped with state-of-the-art optical and electron microscopes. Optical microscopes for conducting phase contrast (PCM) and polarized light microscopy (PLM) were equipped with Nikon DXM-1200 digital cameras. The cameras allow real-time image field searching and provide digital image capture and photographic quality image reproduction using a Fuji Pictography 3500 printer. Scanning electron microscopy was conducted with a Philips XL30 ESEM with single particle elemental analysis provided by a Noran Vantage EDS system. Transmission electron microscopy was conducted with a Philips TECNAI 12 equipped with a Noran EDS system for single particle elemental analysis and a Gatan 780 CCD camera for capturing electron diffraction patterns.

Sierra Research Incorporated

The facilities of the subcontractor, Sierra Research Inc., specific to the project proposal include extensive computer hardware and software capability to construct databases for the organization and assessment of emissions survey data, and a chassis dynamometer cell with instrumented test vehicles to conduct brake wear emissions testing. A Clayton DC-100 chassis dynamometer provides both mechanical and electric simulation, allowing for the testing of vehicles ranging from 1,000 to 9,000 lbs. loaded vehicle weight under a variety of conditions using standard and custom driving cycles. The fully instrumented dynamometer incorporates a constant volume sampling system, and instrumented test vehicles provide a variety of brake system configurations.

Appendix B: Vehicle Information Sheet and the Sample Collection Instructions
INFORMATION-Vehicle Must be on Target List

Brake Shop

Name	
Phone	
Mechanic	
Date	

Target Vehicle

Make	
Year	
Model	
Vin#	
Engine	
Miles Now	
Miles, last R/R	
Date, last R/R	

Brake Sample

Sample #			
	Manufacturer	Part Number	Edge Code
Brake Removed			
Rear Shoe			
Front Shoe			
Brake Installed			
Rear Shoe			
Front Shoe			

INSTRUCTIONS-Collecting Brake Shoes and Drum Dust

(During scheduled brake replacement)

Determine that the vehicle is on the target list provided, which is arranged by make, model, and year. Only collect brake shoes and brake dust from vehicles on the target list. Please use the items in the sealed collection kit to collect brake dust from one brake drum and to collect both brake shoes from the same drum as follows:

1. Once the brake drum is removed, use the plastic razor blade in the plastic tube inside the zip lock bag, to scrape brake dust from the braking surface at the interior edge of the brake drum.
2. Use the same plastic razor blade to scoop the brake dust into the green-topped plastic tube, which originally contained the razor blade.
3. Scoop as much dust as possible into the tube and finally drop the razor blade into the same tube, screw the top on securely, and return to the zip lock bag.
4. Remove both brake shoes from the same wheel where the brake dust was collected, and place into the sampling kit bag.
5. Remove this instructional sheet from the protective plastic sleeve and complete each section of the informational sheet located on the back including the shop, vehicle, and brakes
6. Place the sheet back in the plastic sleeve, seal the sleeve in the zip lock bag with the plastic tube, and place in the kit bag along with the brake shoes. Seal the kit bag with the original bag clip.

THANK YOU FOR YOUR HELP

INFORMATION-Vehicle Must be on Target List

Brake Shop

Name	
Phone	
Mechanic	
Date	

Target Vehicle/Weight Class (circle): T4 T5 T6 T7 T8

Make	
Year	
Model	
Vin#	
Engine	
Miles Now	
Miles, last R/R	
Date, last R/R	

Brake Sample

Sample #			
	Manufacturer	Part Number	Edge Code
Brake Removed			
Rear Shoe			
Front Shoe			
Brake Installed			
Rear Shoe			
Front Shoe			

INSTRUCTIONS-Collecting HDV Friction Material and Drum Dust (During scheduled brake replacement)

Determine that the vehicle is on the target list provided, which is arranged by make, model, and year. Only collect brake shoes and brake dust from vehicles on the target list. Please use the items in the sealed collection kit to collect brake dust from one brake drum and to collect both brake shoes from the same drum as follows:

7. Once the brake drum is removed, use the plastic razor blade in the plastic tube inside the zip lock bag, to scrape brake dust from the braking surface at the interior edge of the brake drum.
8. Use the same plastic razor blade to scoop the dry brake dust (use no solvents) into the green-topped plastic tube, which originally contained the razor blade.
9. Scoop as much dust as possible into the tube and finally drop the razor blade into the same tube, screw the top on securely, and return to the zip lock bag.
10. Remove one brake shoe from the same wheel where the brake dust was collected. Break off a sizable piece (approximately 2" x 2") of brake shoe friction material and place in the plastic bag. Retain the brake shoe core to return for relining.
11. Remove this instructional sheet from the protective plastic sleeve and complete each section of the informational sheet located on the back including the shop, vehicle, and brakes.
12. Place the sheet back in the plastic sleeve, seal the sleeve in the zip lock bag with the plastic tube, and place in the kit bag along with the brake shoes. Seal the kit bag with the original bag clip.

THANK YOU FOR YOUR HELP

Appendix C: Summary of Existing TEM Methods for Asbestos Fiber Analysis

Comparison of TEM Analyses used in Nine Different Asbestos Analytical Methods

Method	Sample Type	Sample Preparation	Parameters to be Counted ^c	Count magnif.	# of SAED inspections required	# of EDS analyses required	# of zone-axis SAED analyses required	Other measurements required
ISO 10312	Air filter	Mount on grid, dissolve filter	Primary fibrous structures > 0.5 um long: 1) fibers > 5:1 2) bundles of [1] 3) disperse clusters of [1] or [2] 4) compact clusters of [1] or [2] 5) disperse matrices attached to [1] or [2] 6) compact matrices attached to [1] or [2] Subcomponent structures > 0.5 um long: 7) [1] within clusters 8) [2] within clusters 9) residual components of clusters 10) [1] within matrices 11) [2] within matrices 12) residual components of matrices	20kx	1 per fiber ^d	1 per fiber ^d	if amphiboles present, 1 per sample ^d	1) Length, width of each structure 2) # of structures > 5 um long 3) # of fibers and bundles of fibers > 5:1, > 5 um 4) # of structures > 3:1, > 5 um length, 0.2-3 um width 5) # of particles with parallel sides, > 3:1, > 5um length, 0.2-3 um width
EPA 100.1	Water sample	Filter, mount on grid, dissolve filter	Fibers > 0.5 um long, > 3:1	20kx	1 per fiber ^d	1 per fiber ^d	if amphiboles present, 1 per sample ^d	1) Length, width of each fiber 2) estimated mass ^a
EPA 100.2 ^g	Water sample	Filter, mount on grid, dissolve filter	Fibers > 10 um long, > 3:1	10kx-20kx	NONE ^e	1 per fiber ^e	NONE ^e	Length, width of each fiber
ARB 427	Air filter from stationary source	mount on grid, dissolve filter	HIGH-MAG (structure sizes not specified): 1. fibers 2. bundles 3. mats 4. particles attached to fibrous structures LOW-MAG: 5. fibers > 5 um long, >3:1, > 0.2 um wide	HIGH-MAG: 20kx-50kx LOW-MAG: 400-4kx;	NONE ^e	1 per fiber ^{e,f}	NONE ^e	Length, width of each structure
NIOSH 7402	Air filter	Mount on grid, dissolve filter	Fibers > 5 um long, > 3:1, > 0.25 um wide	500-1kx	1 per fiber	5-10, plus 1 per every additional 10 fibers	NONE	1) Length, width of each fiber 2) fraction of all fibers which are asbestos

AHERA	Air filter	Mount on grid, dissolve filter	1. Fibers ≥ 0.5 um long, $> 5:1$ 2. Bundles of [1] 3. Clusters of [1] or [2] 4. Matrices with embedded [1] or [2]	15kx-20kx	4 ^b	1 per fiber ^b	NONE	1) # of structures < 5 um long 2) # of structures > 5 um long
EPA 540/2-90/005a, super-fund	Air filter from ambient sample	(redisperse on filter), mount on grid, dissolve filter	HIGH-MAG (> 0.5 um long): 1) fibers $> 5:1$ 2) bundles of [1] 3) fibrous clusters with no ends visible 4) fibrous clusters with ends visible 5) matrices with no fiber ends visible 6) matrices with fiber ends visible 7) [1] within clusters 8) [2] within clusters 9) [1] within matrices 10) [2] within matrices 11) residual 'submatrix' components LOW-MAG: 12) fibers > 5 um long, $> 5:1$	HIGH-MAG: 20kx LOW-MAG: 10kx	1 per fiber ^d	1 per fiber ^d	if amphiboles present, 1 per sample ^d	Length, width of each structure
EPA 600/R-93/116, building material	Bulk building Material	Matrix reduction / homogenization, disperse on filter, mount on grid, dissolve filter	All visible asbestos structures	(Mag. at which largest bundle fills screen)	(not specified)	(not specified)	(not specified)	1) Volume of each structure 2) % asbestos by mass ^a
OSHA 191	Bulk material	(not specified)	Visual estimation of % asbestos	(not specified)	(not specified)	(not specified)	(not specified)	NONE

^a must convert to % mass using assumed size and density factors.

^b corresponds to 70 structures/mm², the critical level up to which all fibers must be identified by SAED. The AHERA Method is ambiguous about whether EDS is necessary for amphiboles beyond this level.

^c For all methods except NIOSH 7402, "fiber" refers to asbestos fibers only, and separate counts are maintained for each asbestos type. For NIOSH 7402, non-asbestos fiber types are counted as well.

^d for routine samples with *unknown* asbestos content. (For routine samples with *well-characterized* asbestos content, lower levels of analysis may be acceptable, e.g., zone-axis SAED not required, or EDS not required. In contrast, for non-routine samples where precise ID of all fibers is necessary, zone-axis SAED should be obtained for *all* fibers. For each fiber, note which of the 3 ID data types [SAED, EDS, and zone-axis SAED] were successfully obtained, so that the appropriate fibers may be tallied for a given level of analysis.)

^e acquisition of SAED patterns is encouraged, but EDS alone is sufficient. Alternatively, for chrysotile, SAED alone is also sufficient. For amphiboles, SAED alone is not sufficient unless it is performed on multiple zone axes (not recommended due to difficulty).

^f for "positive" ID. If EDS cannot be obtained but morphology is consistent with asbestos, denote ID as "tentative".

^g EHLB maintains a certification for EPA 100.2 analysis (US EPA).

(SAED = selected-area electron diffraction; EDS = energy-dispersive x-ray spectroscopy)

Appendix D1: Detailed Protocol to Prepare Samples for TEM Asbestos Analysis

1. Determine the number and type of samples to be prepared
 - 1.1. This procedure covers the preparation of the following types of samples:
 - 1.1.1. brake dust samples
 - 1.1.2. cyclone final filter (PM_{2.5}) samples
 - 1.1.3. cyclone middle stage rinse (PM₁₀ coarse) samples
 - 1.2. A maximum of 4 samples per preparation session is recommended
2. Assemble the following equipment and supplies
 - 2.1. Cahn microbalance in controlled temperature/RH room
 - 2.2. turbo evaporative carbon coater and carbon thread
 - 2.3. proSONIK™ ultrasonic cleaner (Ney Ultrasonic, Inc.)
 - 2.4. stereozoom microscope (optional)
 - 2.5. 1 50mL graduated cylinder – 1 for each dust sample
 - 2.6. glass, 25mm vacuum filtration apparatuses - 1 for each PM₁₀ coarse or dust sample
 - 2.7. 25mm Nuclepore (polycarbonate) filters, 0.1um pore size – 1 for each PM₁₀ coarse or dust sample
 - 2.8. 25mm HA (MCE) backup filters, 0.45um pore size - 1 for each PM₁₀ coarse or dust sample
 - 2.9. 10 mL volumetric pipets - 1 for each PM₁₀ coarse or dust sample
 - 2.10. plastic Petri dishes with covers, 47mm - 1 for each PM₁₀ coarse or dust sample
 - 2.11. glass slides or plastic Petri dishes - 1 for each PM_{2.5}, PM₁₀ coarse, or dust sample
 - 2.12. glass Petri dish bottoms, 47mm (optional)- 1 for each PM_{2.5}, PM₁₀ coarse, or dust sample
 - 2.13. 47mm filter papers cut into quarter-filter wedges- 1 for each PM_{2.5}, PM₁₀ coarse, or dust sample
 - 2.14. 1 glass Petri dish bottom, 125mm (top is optional)
 - 2.15. rubber bulb or electric pipettor
 - 2.16. flat tweezers
 - 2.17. sharp-pointed tweezers
 - 2.18. Scotch tape
 - 2.19. Razor blade
 - 2.20. foam cubes
 - 2.21. small glass bottle with stopper for dispensing chloroform
 - 2.22. AHERA/200 mesh TEM grids
 - 2.23. 0.1-um filtered deionized water and squeeze bottle
 - 2.24. Chloroform, reagent grade
 - 2.25. isopropyl alcohol in squeeze bottle
3. Prepare glassware (for PM₁₀ coarse or dust samples)
 - 3.1. A maximum of 4 samples per preparation session, and thus 4 sets of filtration glassware, is recommended.

- 3.2. Clean 1000mL beaker using the following procedure
 - 3.2.1. Clean with soap and tap water.
 - 3.2.2. Rinse with IPA.
 - 3.2.3. Ultrasonicate with DI, 0.1um-filtered water for 10 min in ProSONIK™
 - 3.3. Repeat steps 3.2.1-3.2.3 for the filtration apparatus tops, glass stopper, and 50mL graduated cylinder. Use the clean 1000mL beaker to hold the apparatus tops, cylinder, and stopper during sonication.
 - 3.4. Discard the water in the beaker and flask, refill each with DI, 0.1um-filtered water, and sonicate again for 6 minutes.
 - 3.5. Connect house vacuum to filter apparatuses and turn vacuum lines ON. Rinse fritted bottoms of each with squeeze bottle of DI, 0.1um-filtered water.
 - 3.6. Clamp apparatus tops to filtration apparatuses and cover top with aluminum foil.
 - 3.7. Record filtration apparatus IDs.
4. Preparation of Brake Dust for TEM
 - 4.1. Weigh 5-6 mg dust and record exact mass.
 - 4.2. Add 45 mL filtered, deionized water to 50 mL graduated cylinder.
 - 4.3. Add 0.5 mL 0.1% OT (detergent).
 - 4.4. Remove 1 mL for blank.
 - 4.5. Transfer brake dust to graduated cylinder.
 - 4.6. Bring up to 50 mL.
 - 4.7. Briefly ultrasonicate graduated cylinder (6 minutes) in precision waveform proSONIK™ ultrasonic cleaner (Ney Ultrasonic, Inc.) to disperse loose clumps.
 - 4.8. Assemble filter funnel using 0.45 um MCE filter for backing and 0.1 um Nuclepore filter.
 - 4.9. Pretreat filter assembly with 10 mL water.
 - 4.10. Shake sample. Do not use magnetic stirring bar!
 - 4.11. Add 10 mL water and 1 mL sample from graduated cylinder to filter funnel.
 - 4.12. Apply vacuum to filter funnel to collect sample on filter.
 - 4.13. Transfer filter to Petri dish.
 - 4.14. Measure the inside diameter of filter funnel to determine filter deposit diameter.
5. Preparation of Cyclone Samples for TEM
 - 5.1. Obtain filter weights.
 - 5.1.1. For PM2.5 fractions (direct on filter)
 - 5.1.1.1. Tare Cahn microbalance.
 - 5.1.1.2. Calibrate microbalance using 20mg standard weight.
 - 5.1.1.3. Pre-weigh polycarbonate filter(s) for sample collection, after passing through Po²¹⁰ static discharge device twice and store in sealed Petri dish with ID label.
 - 5.1.1.4. After sample collection, pass loaded filter, deposit side face-up, through a Po²¹⁰ static discharge device twice.
 - 5.1.1.5. Re-weigh loaded filter.

- 5.1.1.6. Use previously recorded filter pre-weight to determine mass gained during sampling.
- 5.1.2. For PM10 coarse fractions (liquid extract filtration)
 - 5.1.2.1. Follow steps of section 5.1.1 using 0.1um polycarbonate filter used for extract filtration of section 5.2.
 - 5.1.2.2. Follow steps 5.2.1.1-5.2.1.12 to generate filter deposit from the PM10 coarse sample liquid extract.
- 5.2. Filtration of PM10 coarse fractions
 - 5.2.1. For each PM10 coarse sample:
 - 5.2.1.1. Unclamp filtration unit and remove top.
 - 5.2.1.2. Using flat tweezers, place a 0.45um MCE filter on fritted bottom. This works best when frit is dry.
 - 5.2.1.3. Using flat tweezers, place the 0.1um polycarbonate filter weighed in step 5.1.2 on top of the MCE filter.
 - 5.2.1.4. Turn on vacuum to flatten filter.
 - 5.2.1.5. Guide apparatus top straight down onto filter so that the filter does not wrinkle. Replace clamp and turn off vacuum.
 - 5.2.1.6. Agitate PM10 coarse sample tube by hand with a swirling motion to disperse gross agglomerates. (Uniform dispersal of particulates within liquid is not critical, as entire contents of tube will be filtered.)
 - 5.2.1.7. Wet filter with 5 mL IPA.
 - 5.2.1.8. Add 10 mL DI water.
 - 5.2.1.9. Using a 10mL volumetric pipet and bulb or electric pipettor, progressively transfer entire sample from tube into filtration apparatus. Do not allow the water level in the filtration funnel to drop below 10 mL at any time during the filtration.
 - 5.2.1.10. Rinse sample tube with 10 mL water or IPA and filter this rinse.
 - 5.2.1.11. When filter is relatively dry, unclamp top and turn off vacuum.
 - 5.2.1.12. Return polycarbonate filter to plastic Petri dish.
 - 5.2.2. Allow filters to equilibrate overnight with covers slightly ajar in controlled temperature/RH room.
 - 5.2.3. Reweigh all PM10 coarse filters, refer to 5.1.2.1
 - 5.2.4. Determine filtered masses using the pre- and post-filtration weights.
 - 5.2.5. Measure the inside diameter of filter funnel to determine filter deposit diameter.
- 6. Carbon coat each of the filters from Steps 4 and 5 as follows
 - 6.1. Tape filter edges to inside of Petri dish, taking care not to wrinkle filter.
 - 6.2. Place filter/Petri dish in carbon coater chamber.
 - 6.3. Mount double carbon thread (X) and rotate shield in over one of the threads. Connect electrodes across the appropriate terminals.
 - 6.4. Close chamber and pump down to $<10^{-4}$ mbar.
 - 6.5. Turn process ON.

- 6.6. Degas carbon thread and then rotate shield out.
 - 6.7. Coat using short pulses of high current until slide appears relatively dark, making sure to minimize the heat generated. Overheating the filter will increase dissolution time in Jaffe washer.
 - 6.8. Turn process OFF and switch electrodes across second thread.
 - 6.9. Repeat steps 6.5-6.7.
 - 6.10. Vent chamber, return sample to Petri dish, and cover Petri dish.
7. Prepare Jaffe washer:
 - 7.1. Fill small glass bottle with chloroform (use exhaust fan whenever chloroform is open to air).
 - 7.2. The design of the Jaffe washer is not critical as long as it maintains a saturated chloroform atmosphere. Two suggested designs:
 - 7.2.1. [simplest design] Fill a large glass Petri dish bottom with foam cubes. Place 1 filter paper wedge on top of the cubes in each Petri dish and label each with the corresponding filtration number. Using the small bottle of chloroform, fill the large Petri dish half full, so that the cubes and filter paper are just soaked. Leave dish uncovered.
 - 7.2.2. [uses fewer cubes and chloroform, possibly produces a higher vapor concentration] Arrange small glass Petri dish bottoms in large glass Petri dish bottom. Fill each small Petri dish with foam cubes. Place 1 filter paper wedge on top of the cubes in each small Petri dish and label each with the corresponding filtration number. Using the small bottle of chloroform, fill each small Petri dish half full, so that the cubes and filter paper are just soaked. Cover the large Petri dish with its cover.
8. Dissolve filters onto TEM grids using one of the following 2 methods (can be performed with or without the aid of a stereozoom microscope):
 - 8.1. Method 1:
 - 8.1.1. Place 1 AHERA/200 mesh TEM grid onto the slide next to the filter. (For EMS grids, place dark/dull side up so that letters/numbers are backwards).
 - 8.1.2. Use razor to cut small square (~1mm²) from center of filter.
 - 8.1.3. Place filter square on top of TEM grid using sharp-pointed tweezers.
 - 8.1.4. Using sharp-pointed tweezers, place grid-plus-filter “sandwich” on top of the appropriate chloroform-soaked filter paper in the Jaffe washer. The filter square will instantly ‘melt’ onto the grid.
 - 8.1.5. Prepare at least 3 grids per sample by repeating steps (1)-(4).
 - 8.2. Method 2:
 - 8.2.1. Place 1 AHERA/200 mesh TEM grid onto the appropriate chloroform-soaked filter paper in the Jaffe washer. (For EMS grids, place dark/dull side up so that letters/numbers are backwards).
 - 8.2.2. Use razor to cut small square (~1mm²) from center of filter.
 - 8.2.3. Place filter square on top of TEM grid in Jaffe washer using sharp-pointed tweezers. The filter square will instantly ‘melt’ onto the grid.

- 8.2.4. Prepare at least 3 grids per sample by repeating steps (1)-(3).
9. Clear filters in Jaffe washer:
- 9.1. Place Jaffe washer inside a glass desiccator that is as small as possible. No desiccant is required; the desiccator is simply used to contain the chloroform vapors. Cover desiccator.
 - 9.2. Check chloroform levels daily. If any Petri dish is less than half full, remove from desiccator and refill with chloroform, then replace inside desiccator.
 - 9.3. After 1-2 days in Jaffe washer, choose a test grid and inspect in TEM. If no polycarbonate filter pores are visible and fibers are clearly resolved, grids are ready for analysis. If grid is not yet ready, then return to Jaffe washer (may require 4 days or more; if filters were severely overheated during coating, they may not ever completely dissolve).

Appendix D2. Brake Shoe Asbestos Screening Protocol Using Polarized Light Microscopy (PLM)

1. Brake Shoe Sample Login
 - 1.1. Login each sample through the Laboratory Information System (LIMS) using the existing pre-logged sample ID for the collected brake shoe.
 - 1.2. Record the vehicle year, make, and model, as well as, the brake shop shoe collector, date collected, and date received in the laboratory.

2. BFM Sub-Sampling and PLM Slide Preparation
 - 2.1. Inside a chemical fume hood and wearing vinyl gloves, remove the brake shoe from the sealed plastic collection bag.
 - 2.2. Break off several 1 cm² pieces of brake friction material (BFM) from the brake shoe, using 10" End Cutting Nippers and store in a sealed Petri dish labeled with the sample ID
 - 2.3. While still in the fume hood, place the brake shoe back into the sealed plastic sampling kit collection bag and place in sample archive storage.
 - 2.4. In the fume hood, open the labeled Petri dish containing the friction material and examine under a stereoscope for identify the presence of fibers and fiber bundles.
 - 2.5. Apply a drop of 1.550 refractive index oil, used to identify chrysotile asbestos fibers on a clean slide.
 - 2.6. Using sharp tweezers, pull out fibers from the BFM and place in the drop of refractive index oil on the slide
 - 2.7. Re-examine the BFM for other types of fibers and repeat step (6) to transfer all the types of fibers observed in the BFM sample to the oil drop on the slide.
 - 2.8. Seal the sampled portion of slide with a micro cover glass.
 - 2.9. Label the slide with the sample ID, insert the slide horizontally into a 50 mL centrifuge tube, and store centrifuge tube in a horizontal position to prevent the oil drop from flowing off the slide.

3. Chrysotile Screening using PLM
 - 3.1. Power up the PLM, with digital camera, and perform those pre-screening analysis checks from NIOSH Method 9002, required to yield unambiguous identification of chrysotile asbestos in a standard reference sample.
 - 3.2. Place a prepared BFM sample slide to be screened on the PLM stage.
 - 3.3. Record the results of the following Asbestos Sample Screening Schema used to confirm the presence of chrysotile asbestos fibers (expected to be 20-60% of the BFM mass):
 - 3.3.1. Under plain light (no polarization), with 10X objective, observe the color of the fiber. (**chrysotile displays a clear color**).
 - 3.3.2. Under plain light, pull the analyzer slider out (with polarization on, the background turns to pink). Observe if the colors of the fiber disappear when it is parallel to both the horizontal and vertical axes of the cross hair. (**If YES, then this is a chrysotile trait**).

- 3.3.3. With the same setting as the previous step, check if the fibers at, \\\ (upper left to lower right diagonal) direction on the cross hair, appears to be yellow color **and**, /// (upper right to lower left) direction on the cross hair, appears to be blue color. **(If YES, this positive sign of elongation, is a chrysotile trait).**
- 3.3.4. Using the Dispersion Staining objective, and push the analyzer slider in (polarization turned off), and turn the condenser aperture diaphragm ring all the way to the right (reduce the amount of light going through). Check the field of view for the horizontal fibers displaying a magenta color, **and** a blue color in the vertical direction, both relative to the cross hairs. **(If YES, this is a chrysotile trait).**
- 3.4. If **all** of the above PLM screening test characteristics are observed, the BFM is considered to contain **chrysotile asbestos fibers**.
- 3.5. If only **one or none** of the above sub-steps matches the trait of chrysotile, the BFM is considered to **NOT** to contain **chrysotile asbestos fibers**.
- 3.6. If chrysotile fibers cannot be confirmed as present or absent, then fresh BFM samples can be ashed (NIOSH method 9002) to remove any matrix material coating the fibers and re-examined by the above PLM schema. Ashing is not usually required for BFM screening to confirm the presence or absence of chrysotile asbestos fibers, due to the high level expected (20-60% of BFM mass).
- 3.7. Record the screening results in the LIMS for the sample under examination.

Appendix E: Representative Fleet Brake Type Distribution for LDV/MDV
(Summary, vehicle make and model year specific listing available on CD-R)

EMFAC Vehicle Code	Model Year	Front Brake Type			Rear Brake Type		
		Disk	Either	Drum	Disk	Either	Drum
PC*	1973	299	66	25	73	.	317
	1974	239	57	.	64	2	230
	1975	251	13	.	62	1	201
	1976	483	1	.	131	33	320
	1977	674	.	.	115	39	520
	1978	926	.	.	146	58	722
	1979	1269	.	.	309	68	892
	1980	1547	.	.	221	142	1184
	1981	2995	.	.	335	68	2592
	1982	3748	.	.	660	264	2824
	1983	5083	.	.	507	825	3751
	1984	7875	.	.	1013	1229	5633
	1985	10031	.	.	1813	1057	7161
	1986	11577	.	.	2555	900	8122
	1987	13264	.	.	2594	1169	9501
	1988	10695	.	.	1830	1305	7560
	1989	11163	.	.	1852	3353	5958
	1990	10933	.	.	2390	2850	5693
	1991	14386	.	.	2950	4387	7049
	1992	12053	.	.	2751	5559	3743
	1993	11731	.	.	2184	7015	2532
1994	9899	.	.	2346	5670	1883	
1995	13167	.	.	3322	7945	1900	
1996	14533	.	.	3675	8645	2213	
1997	16058	.	.	3907	9763	2388	
1998	14229	.	.	3722	7338	3169	
1999	13869	.	.	3911	8081	1877	
	Total	212977	137	25	45438	77766	89935

* PC = Passenger Cars, all vehicle weights.

EMFAC Vehicle Code	Model Year	Front Brake Type			Rear Brake Type		
		Disk	Either	Drum	Disk	Either	Drum
T1-T3*	1973	402	78	17	.	.	497
	1974	324	44	21	.	.	389
	1975	192	47	21	.	.	260
	1976	506	.	5	.	.	511
	1977	776	.	.	.	.	776
	1978	826	.	.	.	.	826
	1979	970	.	.	.	.	970
	1980	606	.	.	.	.	606
	1981	700	.	.	.	.	700
	1982	904	.	.	.	.	904
	1983	1223	.	.	.	.	1223
	1984	2035	.	.	.	.	2035
	1985	2304	.	.	.	.	2304
	1986	3133	.	.	.	225	2908
	1987	3097	.	.	3	.	3094
	1988	2830	.	.	3	53	2774
	1989	3582	.	.	6	17	3559
	1990	3437	.	.	5	299	3133
	1991	3994	.	.	2	461	3531
	1992	3839	.	.	5	393	3441
	1993	4444	.	.	7	295	4142
1994	4733	.	.	7	260	4466	
1995	5243	.	.	468	586	4189	
1996	5169	.	.	694	546	3929	
1997	6519	.	.	1046	617	4856	
1998	6604	.	.	1159	1449	3996	
1999	7218	.	.	1383	1664	4171	
	Total	75610	169	64	4788	6865	64190
Total	LDV/MDV**	288587	306	89	50226	84631	154125

* See Table 2.3.1 for a complete list of EMFAC Vehicle Code specifications.

** LDV/MDV includes PC, T1, T2, and T3.

EMFAC Vehicle Code	Front Brake Type			Rear Brake Type		
	Disk	Either	Drum	Disk	Either	Drum
1973	211	71	13	.	.	295
1974	170	42	18	.	.	230
1975	67	45	21	.	.	133
1976	201	.	5	.	.	206
1977	340	.	.	.	.	340
1978	216	.	.	.	.	216
1979	371	.	.	.	.	371
1980	287	.	.	.	.	287
1981	325	.	.	.	.	325
1982	551	.	.	.	.	551
1983	748	.	.	.	.	748
1984	1441	.	.	.	.	1441
1985	1559	.	.	.	.	1559
1986	1988	.	.	.	225	1763
1987	2084	.	.	.	.	2084
1988	1708	.	.	.	.	1708
1989	1807	.	.	.	.	1807
1990	1582	.	.	.	244	1338
1991	1694	.	.	.	161	1533
1992	1201	.	.	.	.	1201
199	1196	.	.	.	.	1196
1994	1380	.	.	.	.	1380
1995	739	.	.	79	.	660
1996	1175	.	.	73	197	905
1997	1386	.	.	72	.	1314
1998	849	.	.	32	281	536
1999	915	.	.	.	124	791
Total	26191	158	57	256	1232	24918

* T1 = Light-duty trucks 0 - 3,750 lbs.

EMFAC Vehicle Code	Model Year	Front Brake Type			Rear Brake Type			
		Disk	Either	Drum	Disk	Either	Drum	
T2*	1973	191	7	4	.	.	202	
	1974	154	2	3	.	.	159	
	1975	125	2	.	.	.	127	
	1976	305	.	.	.	.	305
	1977	436	.	.	.	.	436
	1978	610	.	.	.	.	610
	1979	599	.	.	.	.	599
	1980	319	.	.	.	.	319
	1981	375	.	.	.	.	375
	1982	353	.	.	.	.	353
	1983	475	.	.	.	.	475
	1984	594	.	.	.	.	594
	1985	745	.	.	.	.	745
	1986	1145	.	.	.	.	1145
	1987	1013	.	.	.	3	1010	
	1988	1122	.	.	.	3	53	1066
	1989	1775	.	.	.	6	17	1752
	1990	1855	.	.	.	5	55	1795
	1991	2300	.	.	.	2	300	1998
	1992	2638	.	.	.	5	393	2240
	1993	3248	.	.	.	7	295	2946
	1994	3353	.	.	.	7	260	3086
1995	4504	.	.	.	389	586	3529	
1996	3994	.	.	.	621	349	3024	
1997	5098	.	.	.	974	617	3507	
1998	5712	.	.	.	1100	1168	3444	
1999	6006	.	.	.	1354	1540	3112	
	Total	49044	11	7	4476	5633	38953	

* T2 = Light-duty trucks 3,751 - 5,750 lbs.

EMFAC Vehicle Code	Model Year	Front Brake Type			Rear Brake Type		
		Disk	Either	Drum	Disk	Either	Drum
T3*	1997	35	.	.	.	.	35
	1998	43	.	.	27	.	16
	1999	297	.	.	29	.	268
	Total	375	0	0	56	0	319

* T3 = Medium-duty trucks, 5,751 - 8,500 lbs.

Appendix F: Distribution of LDV/MDV on Target List for Field Brake Sampling (Example Target List, full listing available on CD-R)

Make	Model	Year	Class	Frequency	Bendix Field
BUICK	APOLL	1973	PC	0.0010%	BUICK 1973 APOLLO FRONT DRUM BRAKE B - 246 S - RS246
BUICK	APOLL	1974	PC	0.0007%	BUICK 1974 APOLLO FRONT DRUM BRAKE B - 246 S - RS246
BUICK	APOLL	1975	PC	0.0003%	BUICK 1975 APOLLO FRONT DISC BRAKE B - 245 S - RS245
BUICK	CENTU	1973	PC	0.0017%	BUICK 1973 CENTURY (RWD) 9 1/2 X 2 REAR BRAKE B - 245 S - RS245
BUICK	CENTU	1974	PC	0.0003%	BUICK 1974 CENTURY (RWD) 9 1/2 X 2 REAR BRAKE B - 245 S - RS245
BUICK	CENTU	1975	PC	0.0010%	BUICK 1975 CENTURY (RWD) 9 1/2 X 2 REAR BRAKE B - 245 S - RS245
BUICK	CENTU	1977	PC	0.0007%	BUICK 1977 CENTURY (RWD) REAR DRUM BRAKE B - 462 S - RS462
BUICK	CENTU	1978	PC	0.0014%	BUICK 1978 CENTURY (RWD) REAR DRUM BRAKE B - 514 S - RS514
BUICK	CENTU	1980	PC	0.0062%	BUICK 1980 CENTURY (RWD) 9 1/2 X 2 REAR BRAKE B - 514 S - RS514
BUICK	CENTU	1981	PC	0.0173%	BUICK 1981 CENTURY (RWD) 9 1/2 X 2 REAR BRAKE B - 514 S - RS514
BUICK	CENTU	1985	PC	0.0772%	BUICK 1985 CENTURY (FWD) STATION WAGON JA-2, JA-8 (\$) BRAKE SYSTEM B - 552 S - RS552
BUICK	CENTU	1986	PC	0.0751%	BUICK 1986 CENTURY (FWD) STATION WAGON JA-2, JA-8 (\$) BRAKE SYSTEM B - 552 S - RS552
BUICK	CENTU	1987	PC	0.0616%	BUICK 1987 CENTURY (FWD) STATION WAGON JA-2, JA-8 (\$) BRAKE SYSTEM B - 552 S - RS552
BUICK	CENTU	1988	PC	0.0256%	BUICK 1988 CENTURY (FWD) STATION WAGON JA-2, JA-8 (\$) BRAKE SYSTEM B - 552 S - RS552
BUICK	CENTU	1989	PC	0.0436%	BUICK 1989 CENTURY (FWD) STATION WAGON JA-2, JA-8 (\$) BRAKE SYSTEM B - 552 S - RS552
BUICK	CENTU	1990	PC	0.0360%	BUICK 1990 CENTURY (FWD) STATION WAGON B - 552 S - RS552
BUICK	CENTU	1991	PC	0.0419%	BUICK 1991 CENTURY (FWD) STATION WAGON B - 552 S - RS552
BUICK	CENTU	1992	PC	0.0311%	BUICK 1992 CENTURY (FWD) STATION WAGON B - 552 S - RS552
BUICK	CENTU	1993	PC	0.0201%	BUICK 1993 CENTURY (FWD) STATION WAGON B - AF636 S - RS636
BUICK	CENTU	1994	PC	0.0270%	BUICK 1994 CENTURY (FWD) STATION WAGON B - AF636 S - RS636
BUICK	CENTU	1995	PC	0.0235%	BUICK 1995 CENTURY (FWD) STATION WAGON B - AF636 S - RS636
BUICK	CENTU	1996	PC	0.0221%	BUICK 1996 CENTURY (FWD) STATION WAGON B - AF636 S - RS636
BUICK	CENTU	1997	PC	0.0208%	BUICK 1997 CENTURY (FWD) REAR DRUM BRAKE B - AF636 S - RS636
BUICK	CENTU	1998	PC	0.0547%	BUICK 1998 CENTURY (FWD) REAR DRUM BRAKE B - AF636 S - RS636
BUICK	CENTU	1999	PC	0.0626%	BUICK 1999 CENTURY (FWD) REAR DRUM BRAKE B - AF636 S - RS636
BUICK	ELECT	1977	PC	0.0031%	BUICK 1977 ELECTRA (RWD) 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1978	PC	0.0048%	BUICK 1978 ELECTRA (RWD) 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1979	PC	0.0024%	BUICK 1979 ELECTRA (RWD) 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1980	PC	0.0017%	BUICK 1980 ELECTRA (RWD) 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1981	PC	0.0031%	BUICK 1981 ESTATE WAGON 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1982	PC	0.0048%	BUICK 1982 ELECTRA (RWD) 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1983	PC	0.0083%	BUICK 1983 ELECTRA (RWD) 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1984	PC	0.0076%	BUICK 1984 ELECTRA (RWD) 11 X 2 REAR BRAKE B - 462 S - RS462
BUICK	ELECT	1985	PC	0.0408%	BUICK 1985 CENTURY (FWD) STATION WAGON JA-2, JA-8 (\$) BRAKE SYSTEM B - 552 S - RS552
BUICK	ELECT	1986	PC	0.0315%	BUICK 1986 ELECTRA (FWD), PARK AVENUE, PARK AVENUE ULTRA 8.86 X 1.77 REAR BRAKE B - 552 S - RS552
BUICK	ELECT	1987	PC	0.0322%	BUICK 1987 LESABRE (FWD) REAR DRUM BRAKE B - 564 S - RS564

Appendix G: Representative Fleet Brake Type Distribution for HDV
(Summary, Vehicle make and model year specific listing available on CD-R)

EMFAC Vehicle Code	Model Year	Count	Front Brakes			Rear Brakes			
			Disk	Either	Drum	Disk	Either	Drum	
T4*	1985	1	.	.	1	.	.	1	
	1986	1	.	.	1	.	.	1	
	1987	1	.	.	1	.	.	1	
	1988	3	.	.	3	.	.	3	
	1989	4	1	.	3	1	.	3	
	1990	2	1	.	1	1	.	1	
	1991	1	.	.	1	.	.	1	
	1992	2	.	.	2	.	.	2	
	1993	3	1	.	2	.	.	3	
	1994	3	.	.	3	.	.	3	
	1995	4	1	.	3	.	.	4	
	1996	4	2	.	2	.	.	4	
	1997	4	1	.	3	.	.	4	
	1998	3	1	.	2	1	.	2	
	1999	3	2	.	1	2	.	1	
	2000	2	2	.	.	2	.	.	
	2001	3	.	.	3	.	.	3	
	2002	3	.	.	3	.	.	3	
	Total	47	12	.	.	35	7	.	40
	T5**	1973	2	.	.	2	.	.	2
1974		1	.	.	1	.	.	1	
1975		2	.	.	2	.	.	2	
1976		2	.	.	2	.	.	2	
1977		1	.	.	1	.	.	1	
1978		2	.	.	2	.	.	2	
1979		1	.	.	1	.	.	1	
1981		2	.	.	2	.	.	2	
1982		1	.	.	1	.	.	1	
1984		1	1	.	.	.	.	1
1986		2	2	.	.	.	1	1	
1987		1	.	.	1	.	.	1	
1988		1	1	.	.	1	.	.	
1989		1	.	.	1	.	.	1	
1993		1	.	.	1	.	.	1	
1994		1	1	.	.	1	.	.	
1996		1	.	.	1	.	.	1	
1998		1	.	.	1	.	.	1	
2000		2	.	.	2	.	.	2	
2001		3	1	.	2	1	.	2	
Total	29	6	.	.	23	3	1	25	

* T4 = Light-heavy duty trucks, 8,501 – 10,000 lbs.

** T5 = Light-heavy duty trucks, 10,001 - 14,000 lbs.

EMFAC Vehicle Code	Model Year	Count	Front Brakes			Rear Brakes			
			Disk	Either	Drum	Disk	Either	Drum	
T6*	1973	6	.	.	6	.	.	6	
	1974	7	.	.	7	.	.	7	
	1975	4	.	.	4	.	.	4	
	1976	3	.	.	3	.	.	3	
	1977	5	.	.	5	.	.	5	
	1978	8	.	.	8	.	.	8	
	1979	7	.	.	7	.	.	7	
	1980	3	.	.	3	.	.	3	
	1981	5	.	.	5	.	.	5	
	1982	1	.	.	1	.	.	1	
	1983	5	2	.	3	1	1	3	
	1984	5	5	.	.	1	3	1	
	1985	3	3	.	.	1	1	1	
	1986	6	5	.	.	1	1	2	3
	1987	4	2	.	.	2	1	1	2
	1988	5	4	.	.	1	2	.	3
	1989	2	1	.	.	1	1	.	1
	1990	3	.	.	.	3	.	.	3
	1991	2	.	.	.	2	.	.	2
	1992	3	1	.	.	2	1	.	2
	1993	2	1	.	.	1	1	.	1
	1994	3	1	.	.	2	1	.	2
	1995	3	1	.	.	2	1	.	2
	1996	2	2	.	.	.	2	.	.
	1997	4	2	.	.	2	2	.	2
	1998	2	1	.	.	1	1	.	1
	1999	3	.	.	.	3	.	.	3
	2000	4	1	.	.	3	1	.	3
2001	4	1	.	.	3	1	.	3	
2002	1	.	.	.	1	.	.	1	
2003	1	.	.	.	1	.	.	1	
Total		116	33	.	83	19	8	89	

* T6 = Medium-heavy duty trucks, 14,001 – 33,000 lbs.

EMFAC Vehicle Code	Model Year	Count	Front Brakes			Rear Brakes		
			Disk	Either	Drum	Disk	Either	Drum
T7*	1974	1	.	.	1	.	.	1
	1975	1	1	.	.	.	.	1
	1976	1	.	.	1	.	.	1
	1978	1	.	.	1	.	.	1
	1980	4	.	.	4	.	.	4
	1981	2	.	.	2	.	.	2
	1982	1	.	.	1	.	.	1
	1983	2	2	.	.	1	1	.
	1984	4	1	.	3	1	.	3
	1985	6	4	.	2	1	1	4
	1986	3	3	.	.	1	.	2
	1987	7	4	.	3	1	.	6
	1988	4	2	.	2	1	.	3
	1989	2	1	.	1	.	.	2
	1990	7	2	.	5	2	.	5
	1991	1	.	.	1	.	.	1
	1992	4	1	.	3	1	.	3
	1993	3	.	.	3	.	.	3
	1995	2	1	.	1	1	.	1
	1996	2	.	.	2	.	.	2
1997	3	2	.	1	2	.	1	
1998	1	1	.	.	1	.	.	
1999	2	.	.	2	.	.	2	
2003	1	.	.	1	.	.	1	
	Total	65	25	.	40	13	2	50

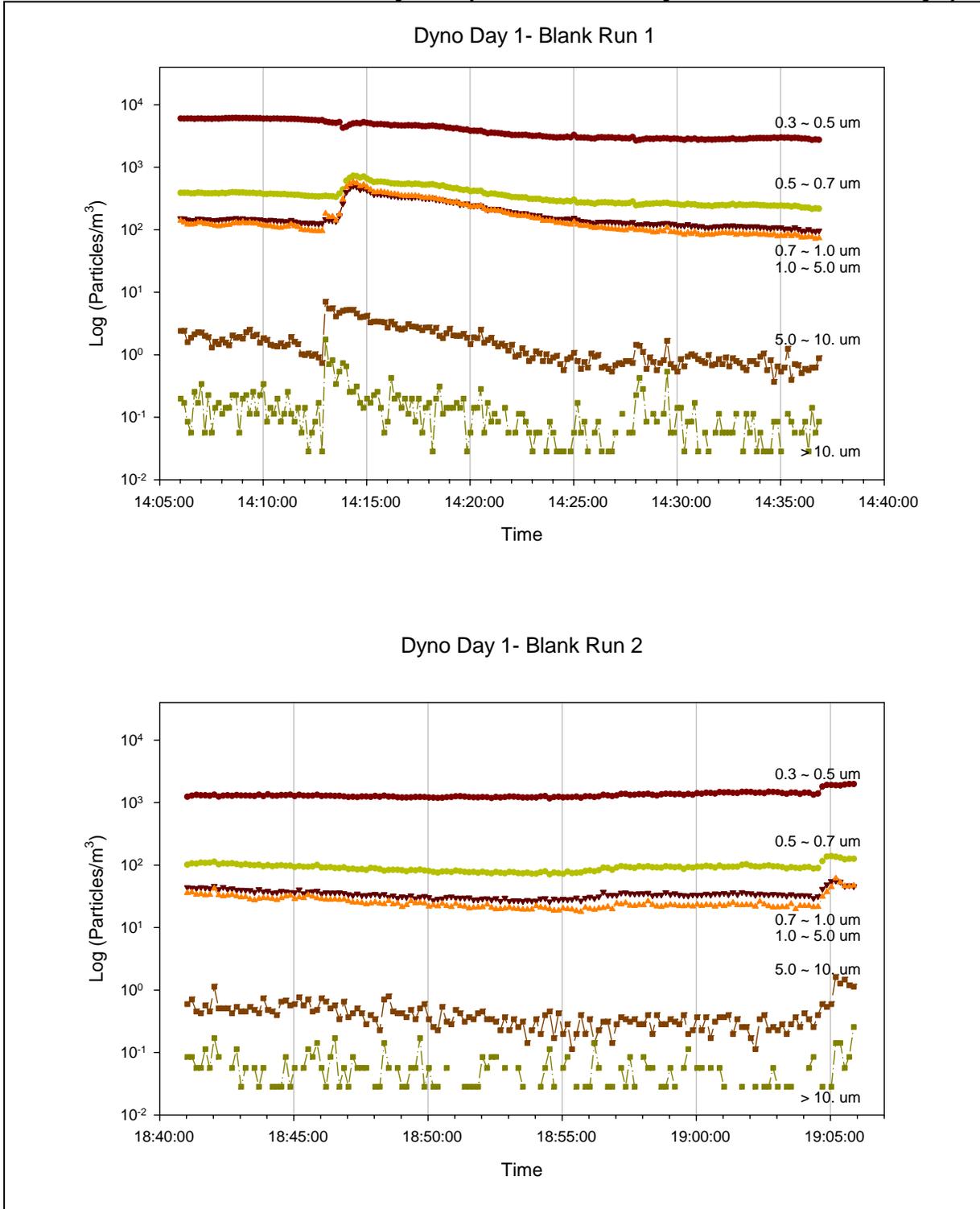
* T7 = Heavy-heavy duty trucks 33,001 – 60,000 lbs.

EMFAC Vehicle Code	Model Year	Count	Front Brakes			Rear Brakes		
			Disk	Either	Drum	Disk	Either	Drum
T8*	1973	3	.	.	3	.	.	3
	1974	2	.	.	2	.	.	2
	1976	1	.	.	1	.	.	1
	1977	4	1	.	3	.	.	4
	1979	5	2	.	3	1	.	4
	1980	3	.	.	3	.	.	3
	1981	3	.	.	3	.	.	3
	1982	4	2	.	2	.	.	4
	1983	1	.	.	1	.	.	1
	1984	2	1	.	1	.	.	2
	1985	1	.	.	1	.	.	1
	1986	5	.	.	5	.	.	5
	1987	1	1	.	.	.	.	1
	1988	3	1	.	2	.	.	3
	1989	3	3	.	.	1	.	2
	1990	2	.	.	2	.	.	2
	1991	1	.	.	1	.	.	1
	1992	1	.	.	1	.	.	1
	1993	1	.	.	1	.	.	1
	1994	1	.	.	1	.	.	1
	1995	1	.	.	1	.	.	1
	1996	4	.	.	4	.	.	4
	1997	3	.	.	3	.	.	3
	1998	4	.	.	4	.	.	4
	1999	2	.	.	2	.	.	2
2000	3	.	.	3	.	.	3	
2001	3	.	.	3	.	.	3	
2002	2	.	.	2	.	.	2	
Total		69	11	.	58	2	.	67
Total HDV**		326	87	.	239	44	11	271

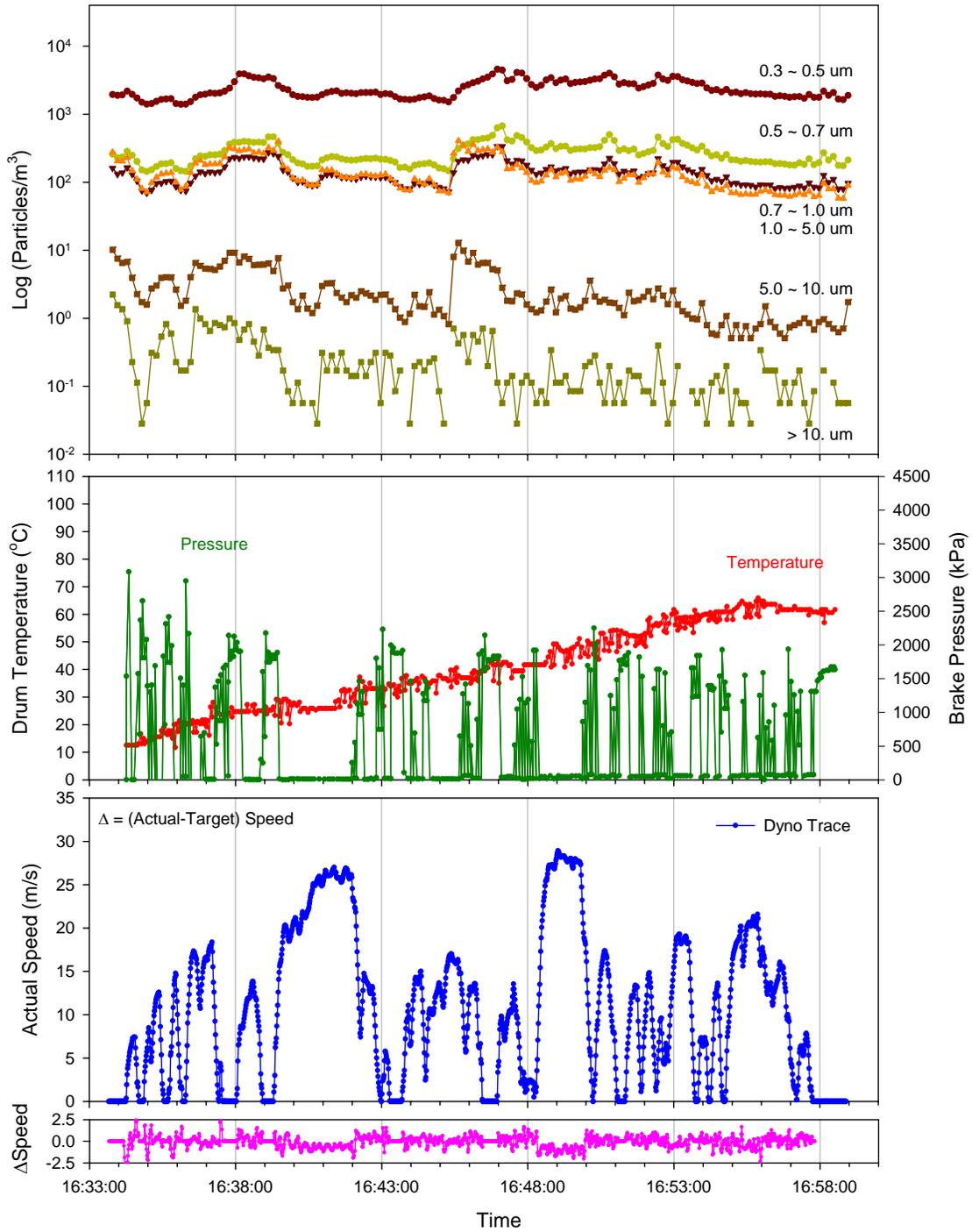
* T8 = Line-haul trucks 60,000+ lbs.

** HDV includes T4, T5, T6, T7, and T8.

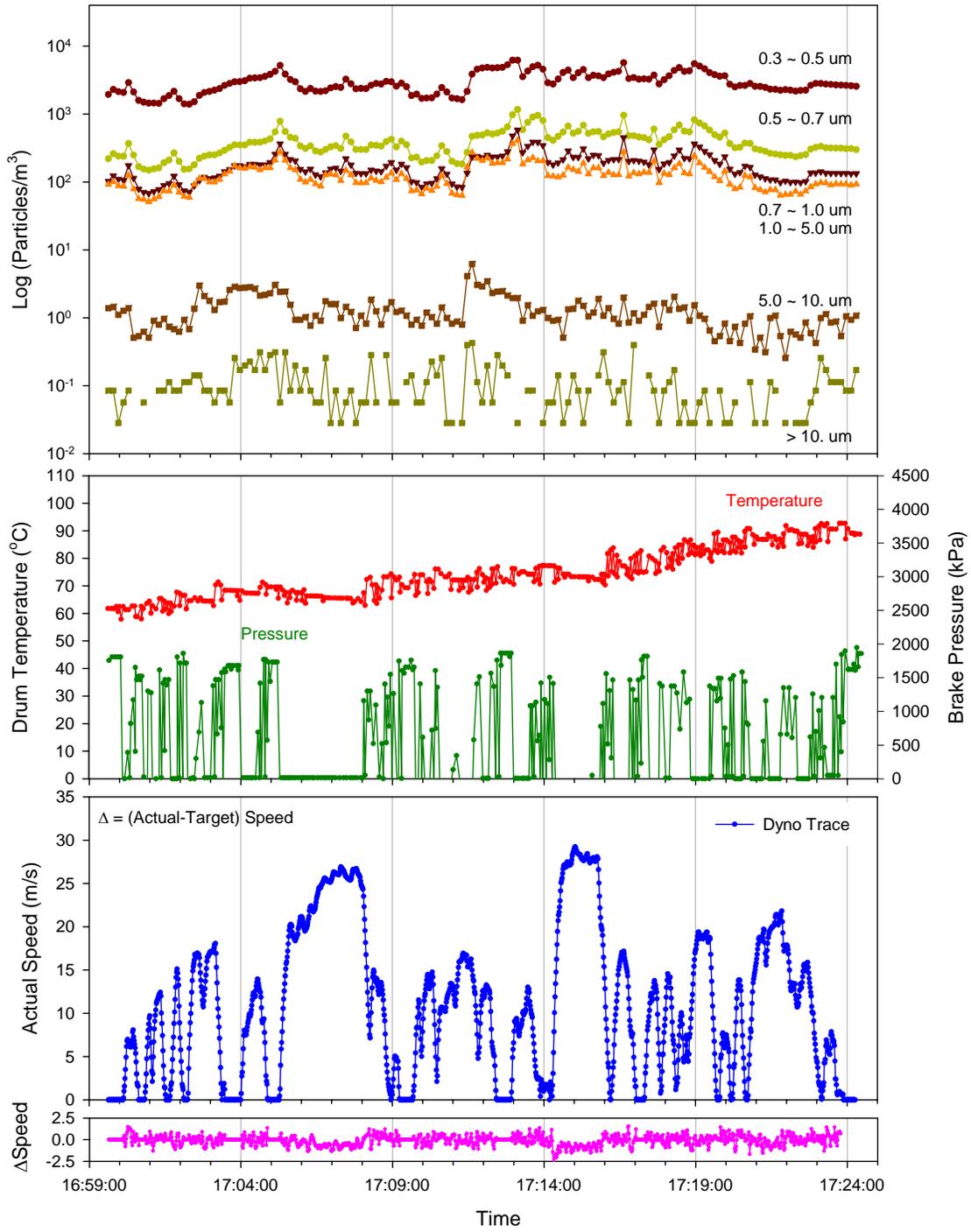
Appendix H: Real-time Sensor Measurements for Test Vehicle Dynamometer Brake Emission Cycles (LA92 ran on Days 1-2 and LA4 on Day3)



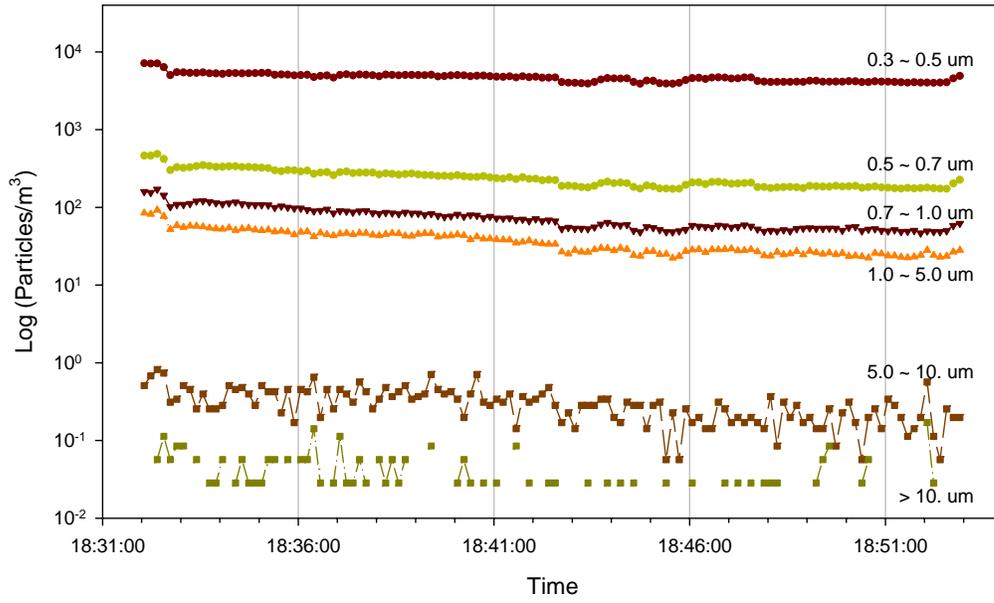
Dyno Day 1- Run 1



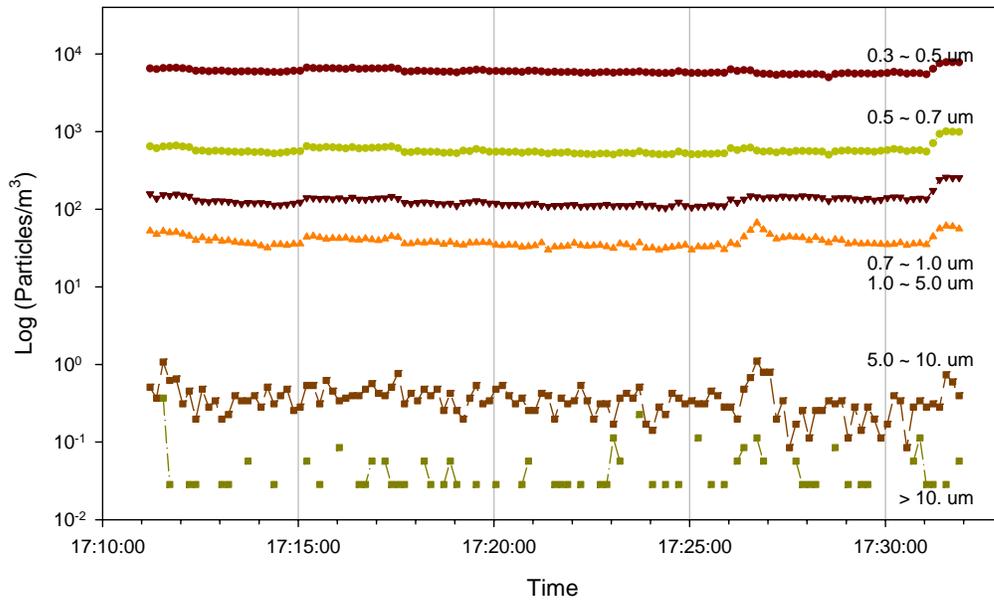
Dyno Day 1- Run 2



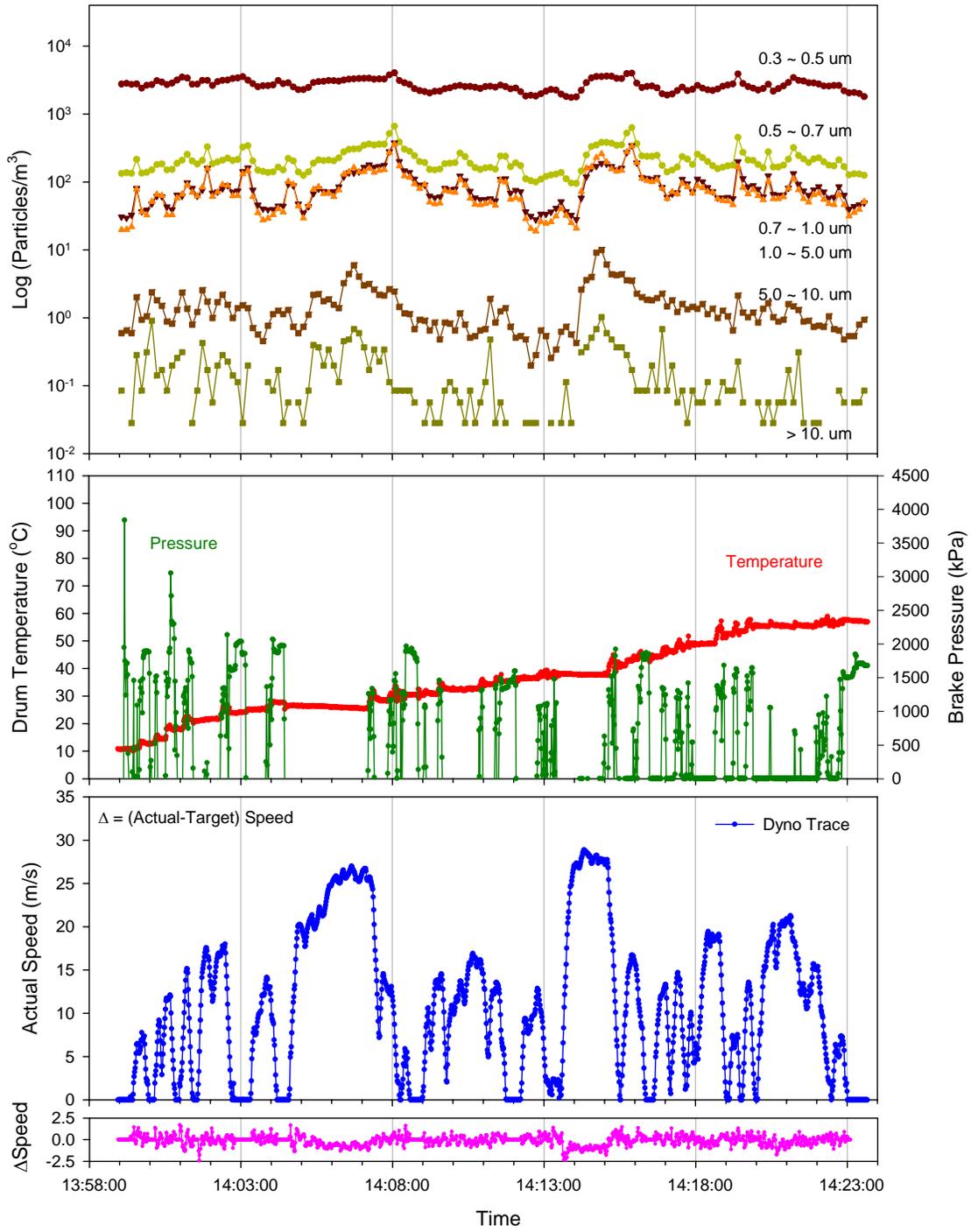
Dyno Day 2- Blank Run 1



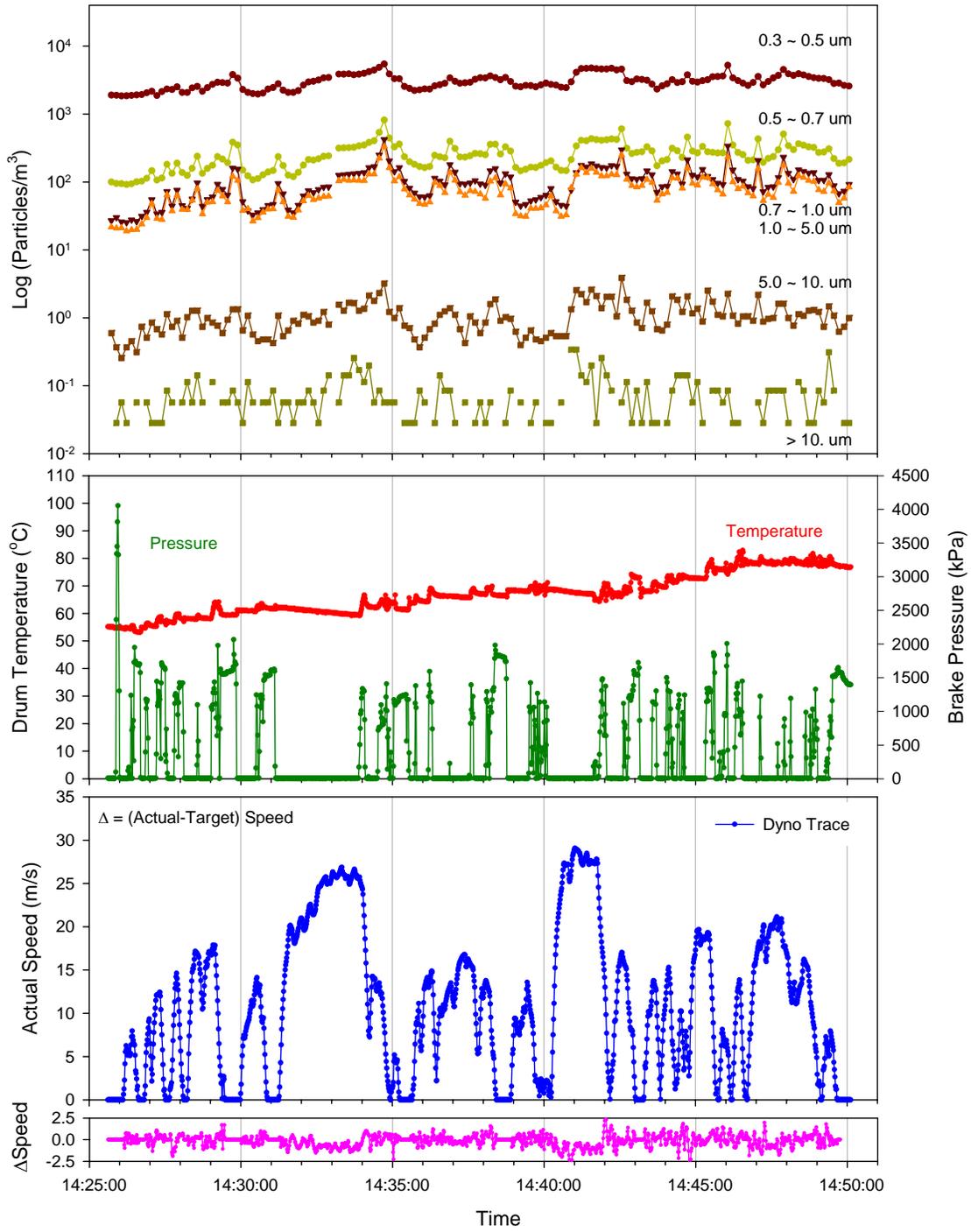
Dyno Day 3- Blank Run 1



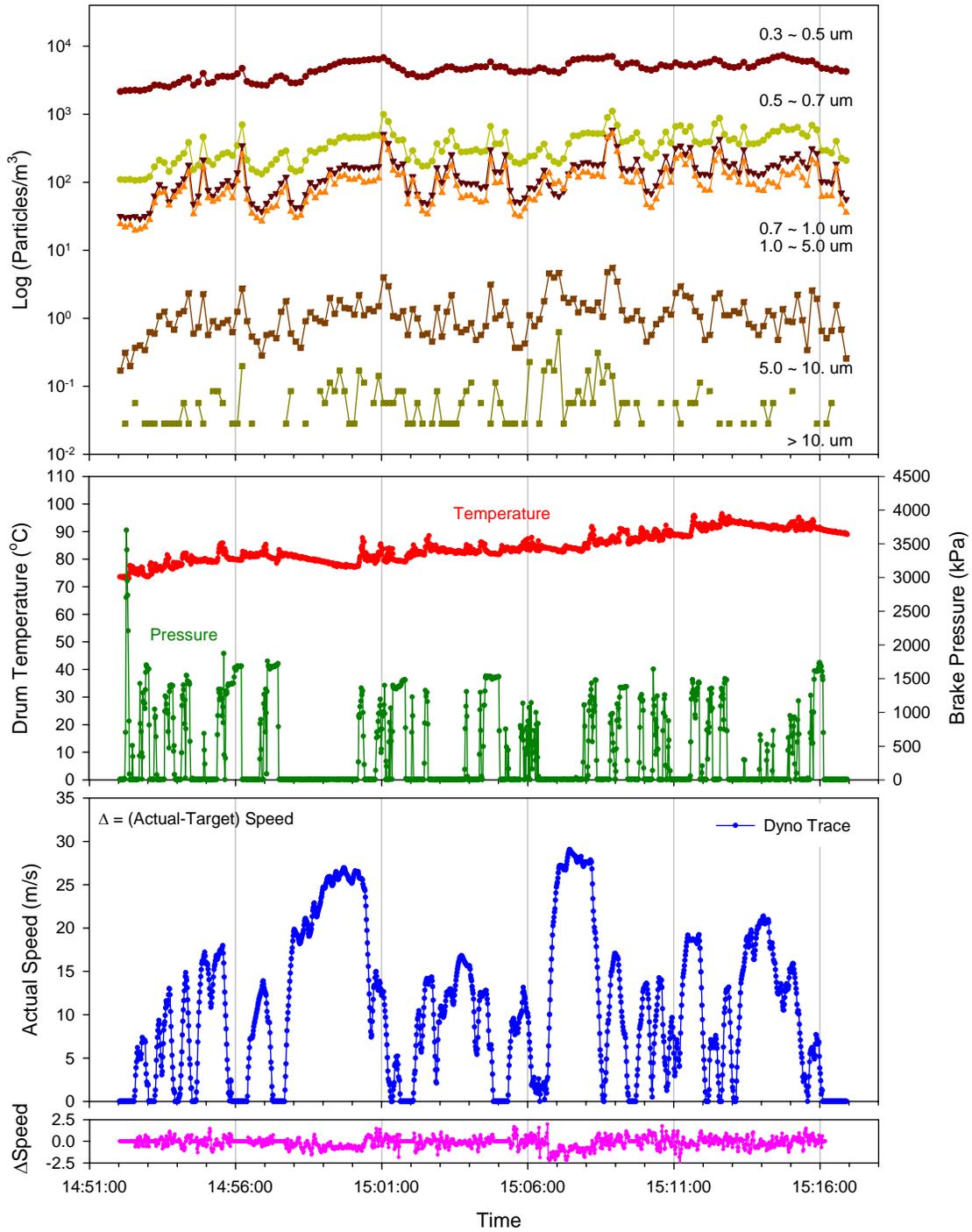
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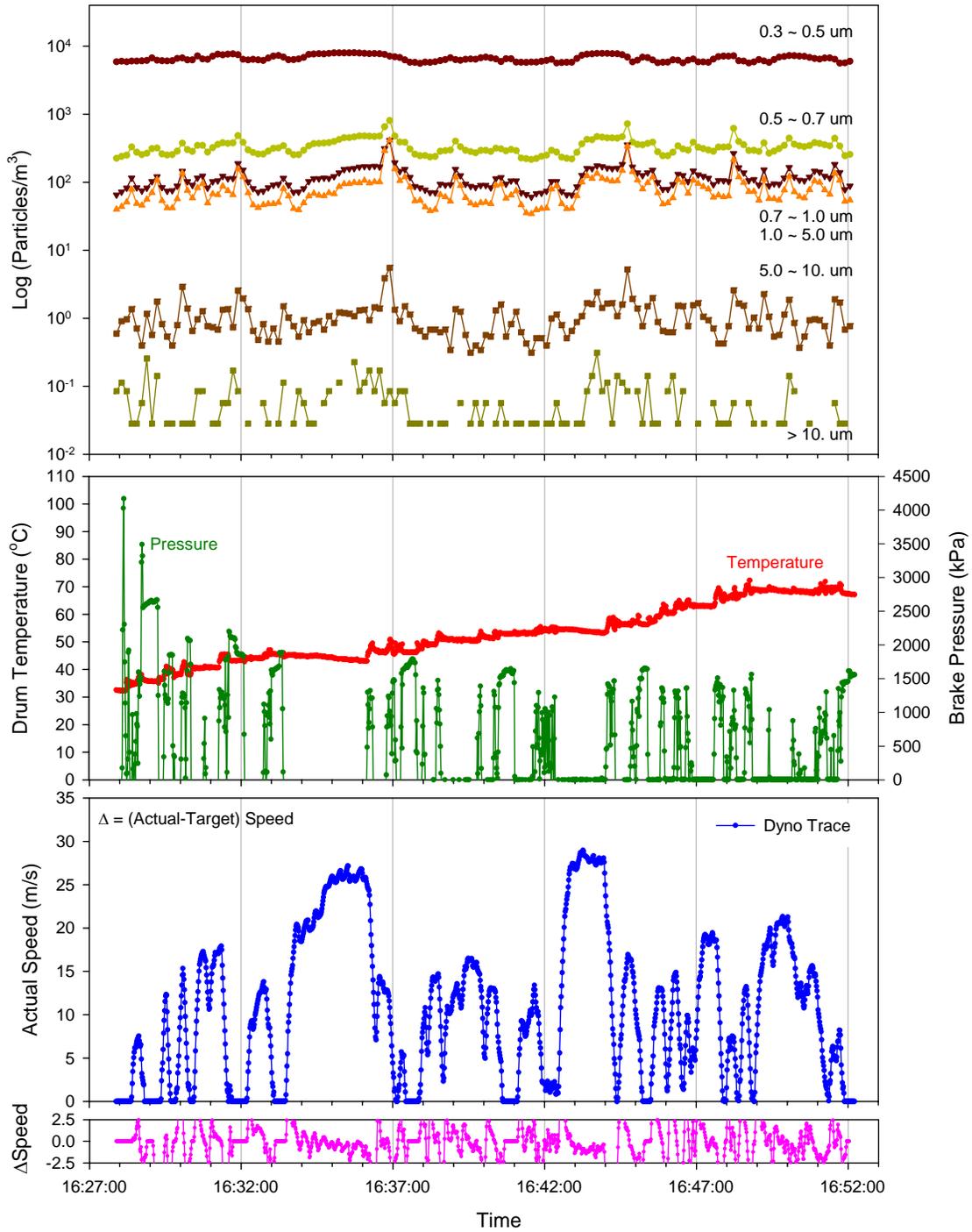
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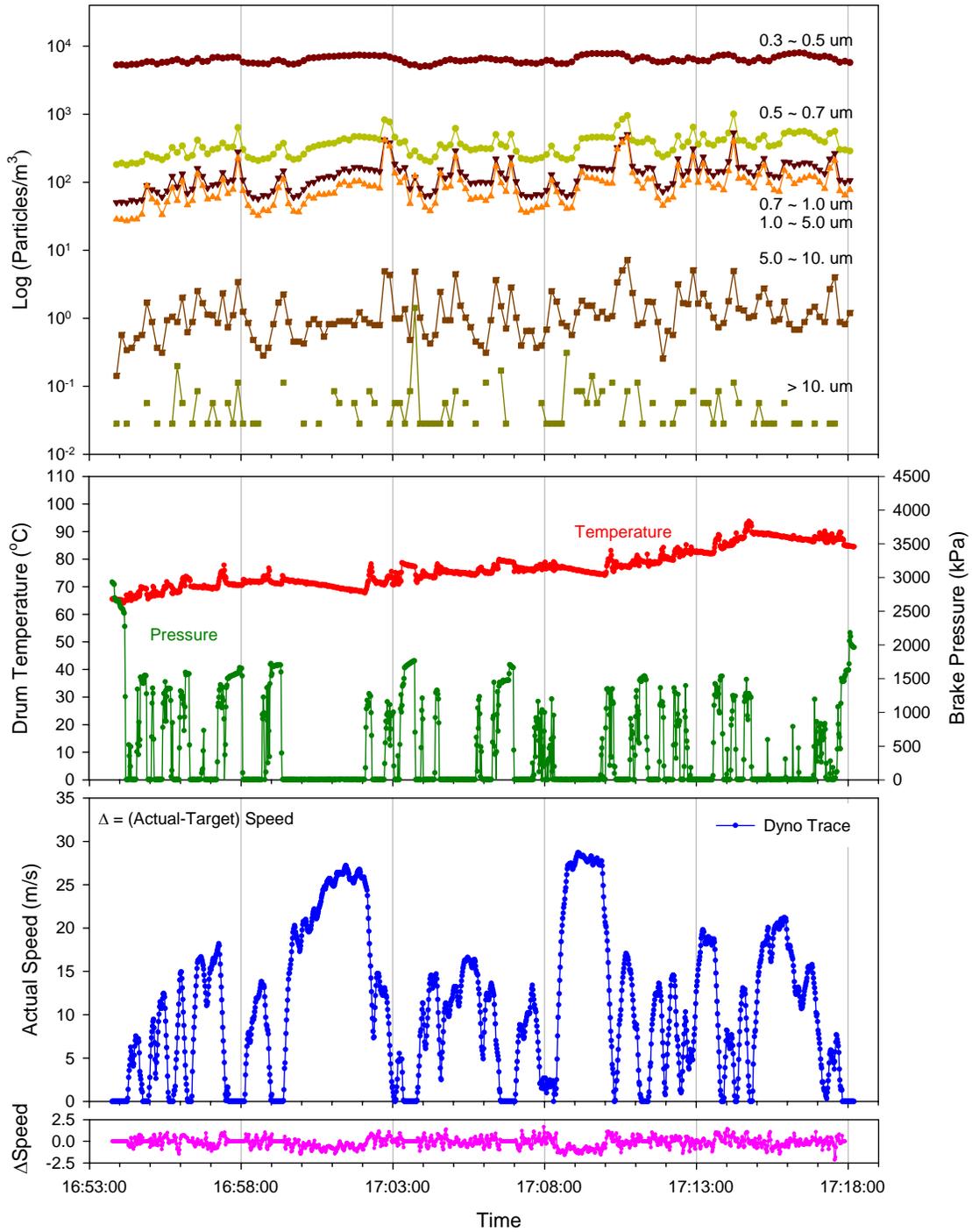
Dyno Day 2- Run 3



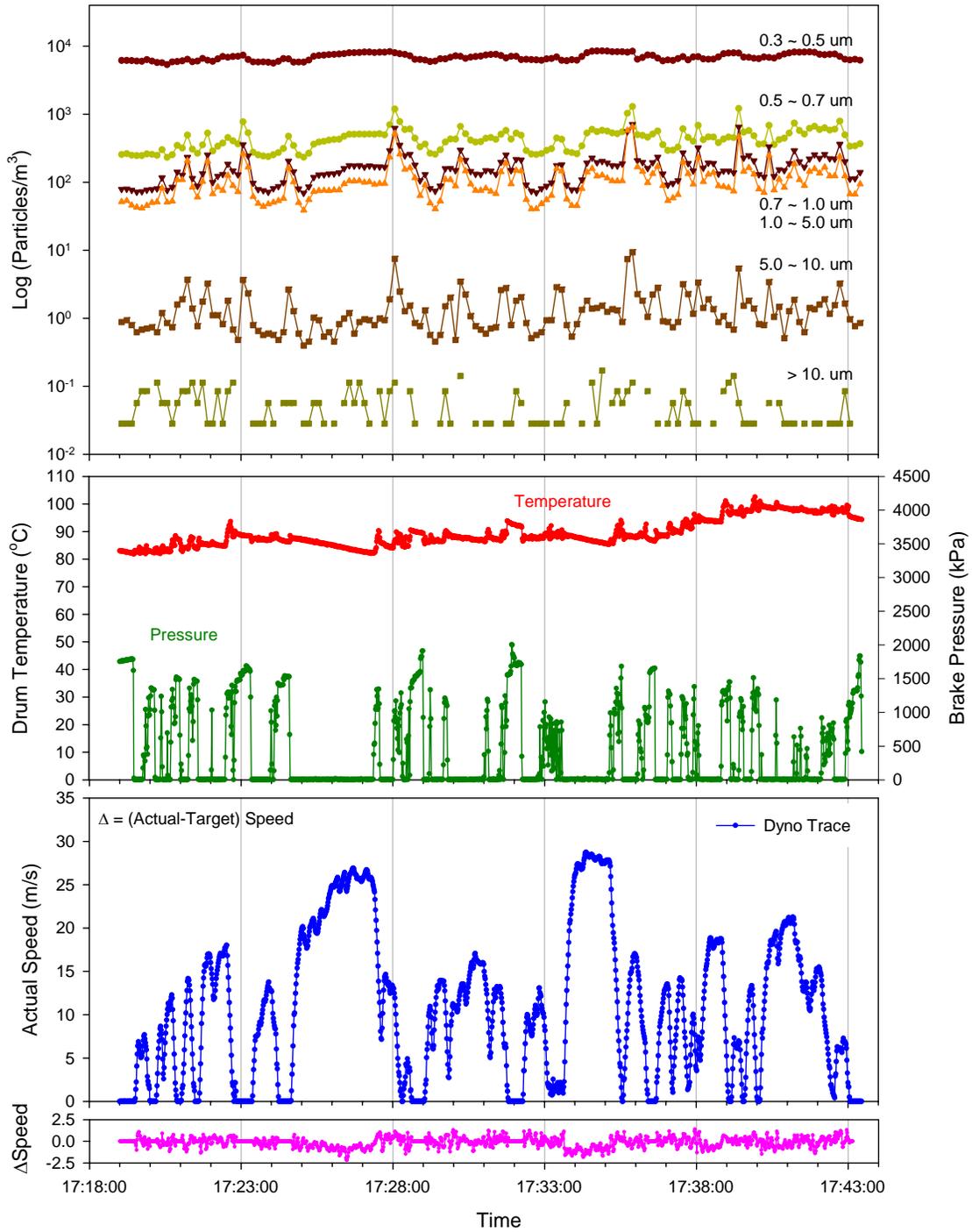
Dyno Day 2- Run 4



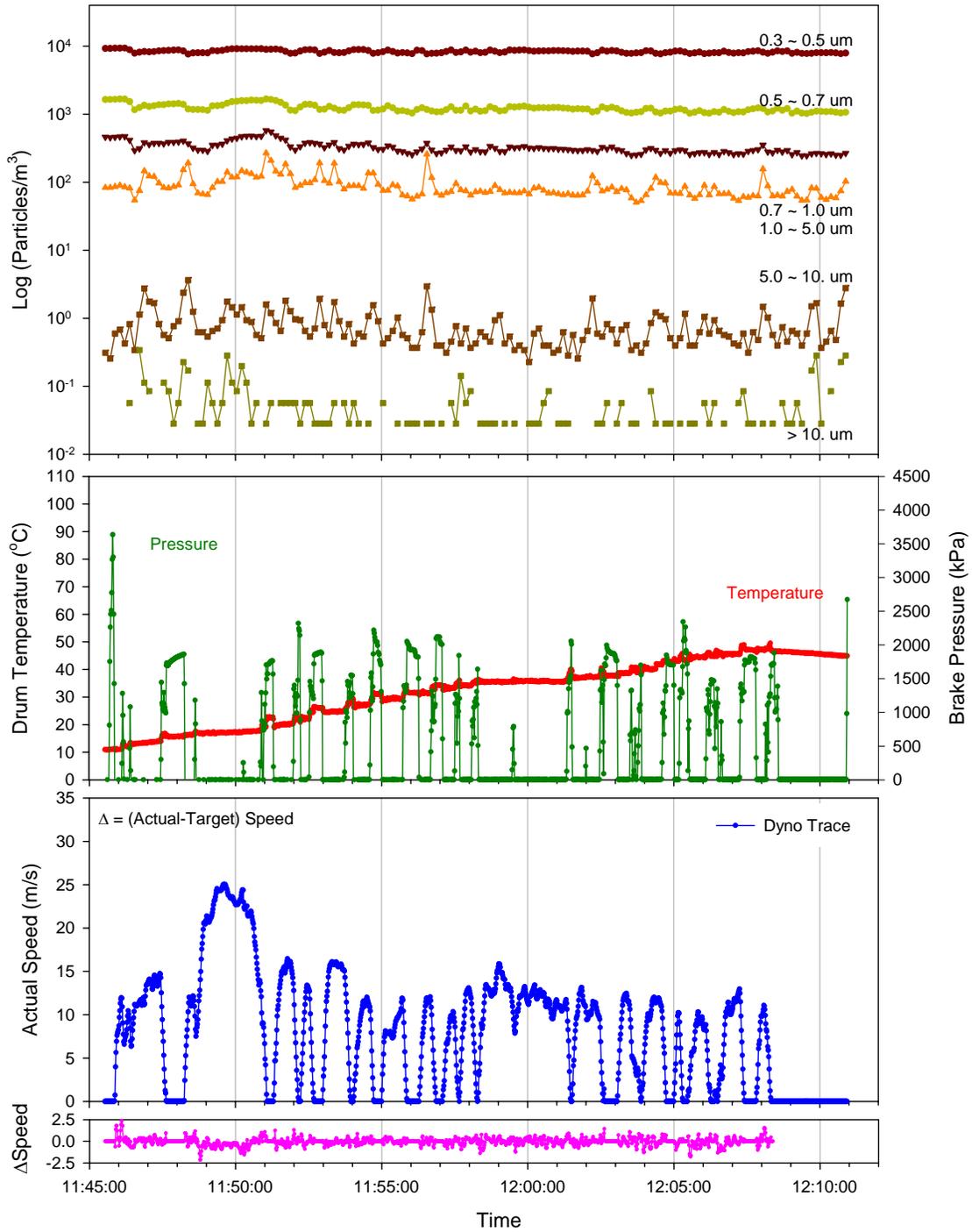
Dyno Day 2- Run 5



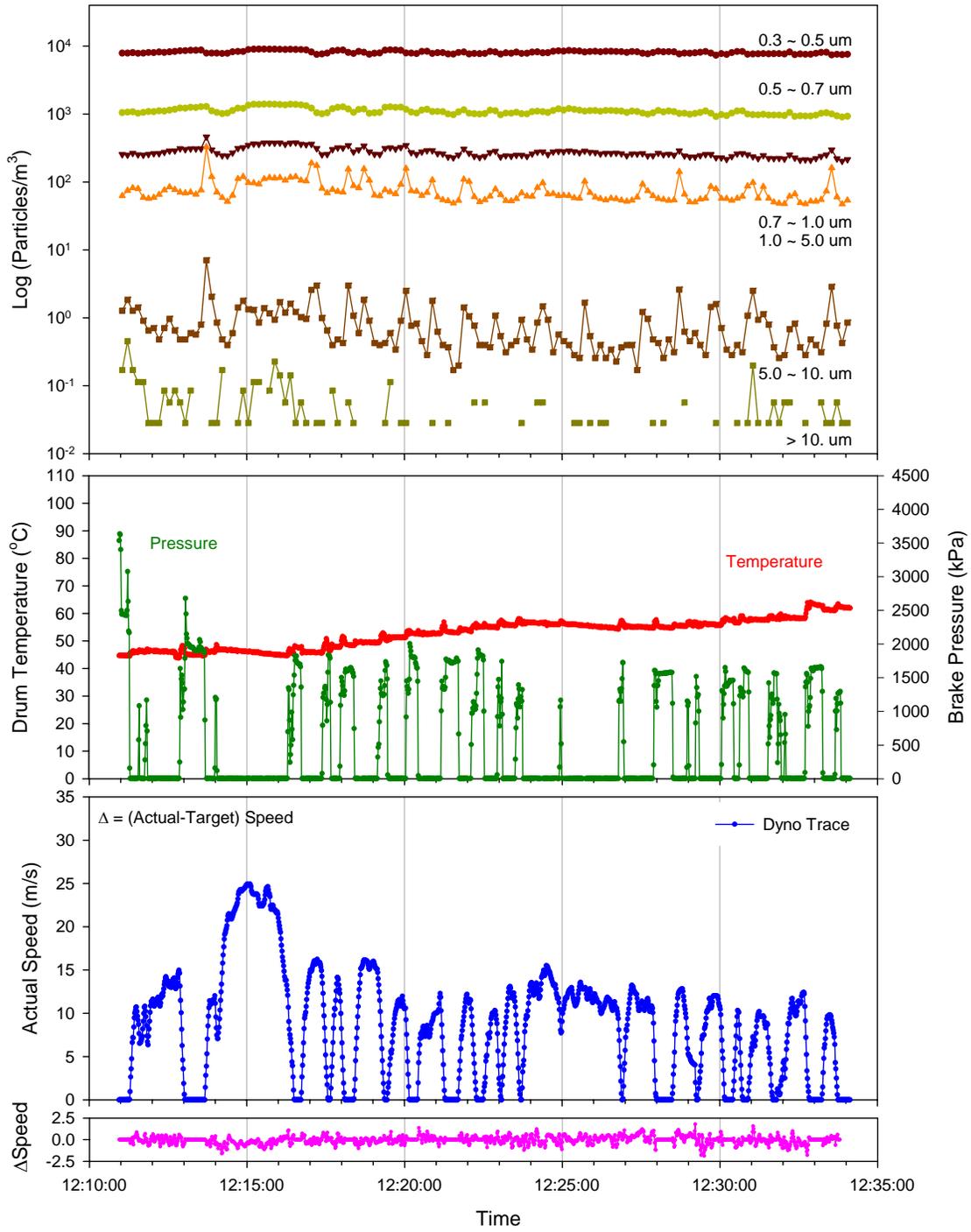
Dyno Day 2- Run 6



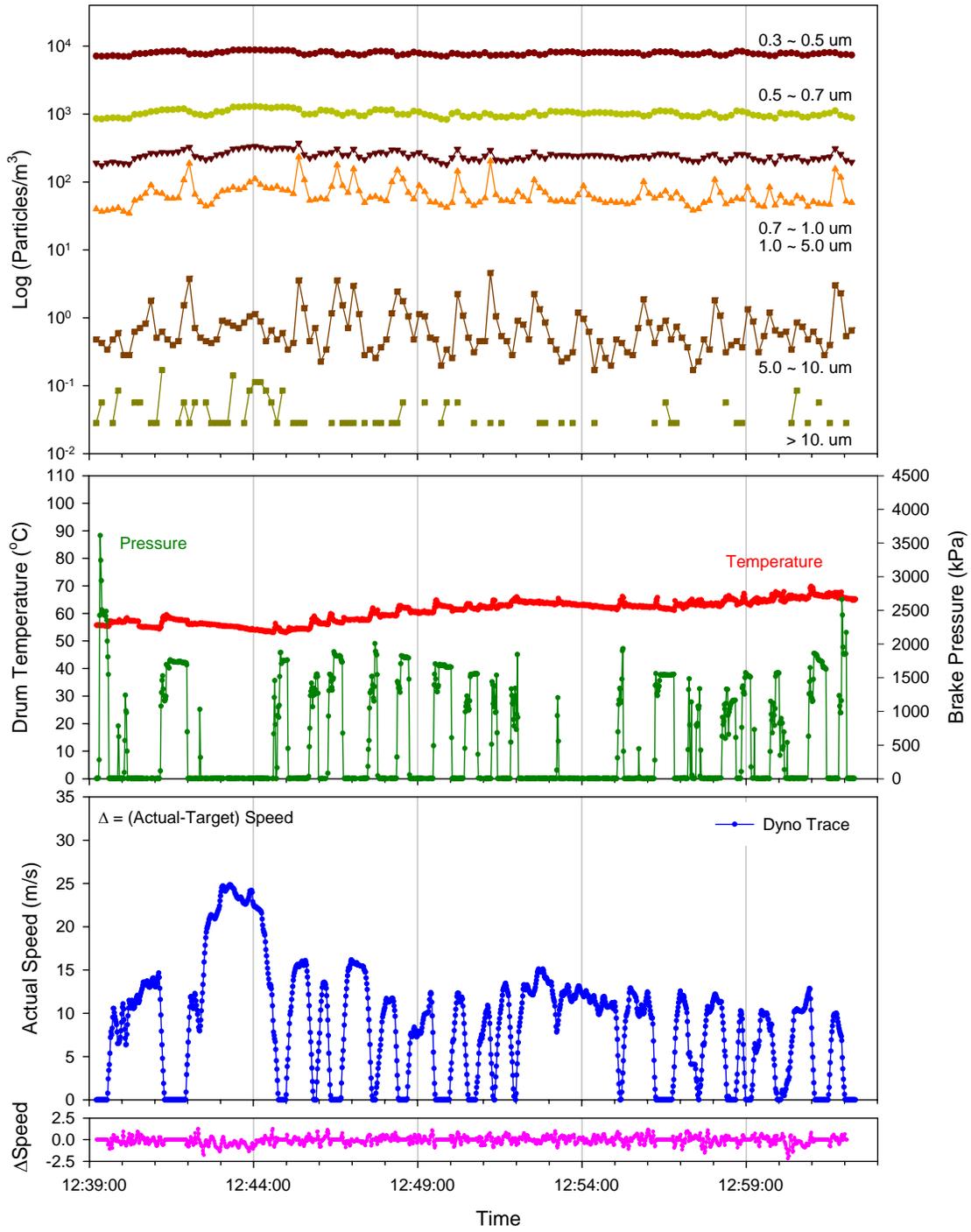
Dyno Day 3- Run 1



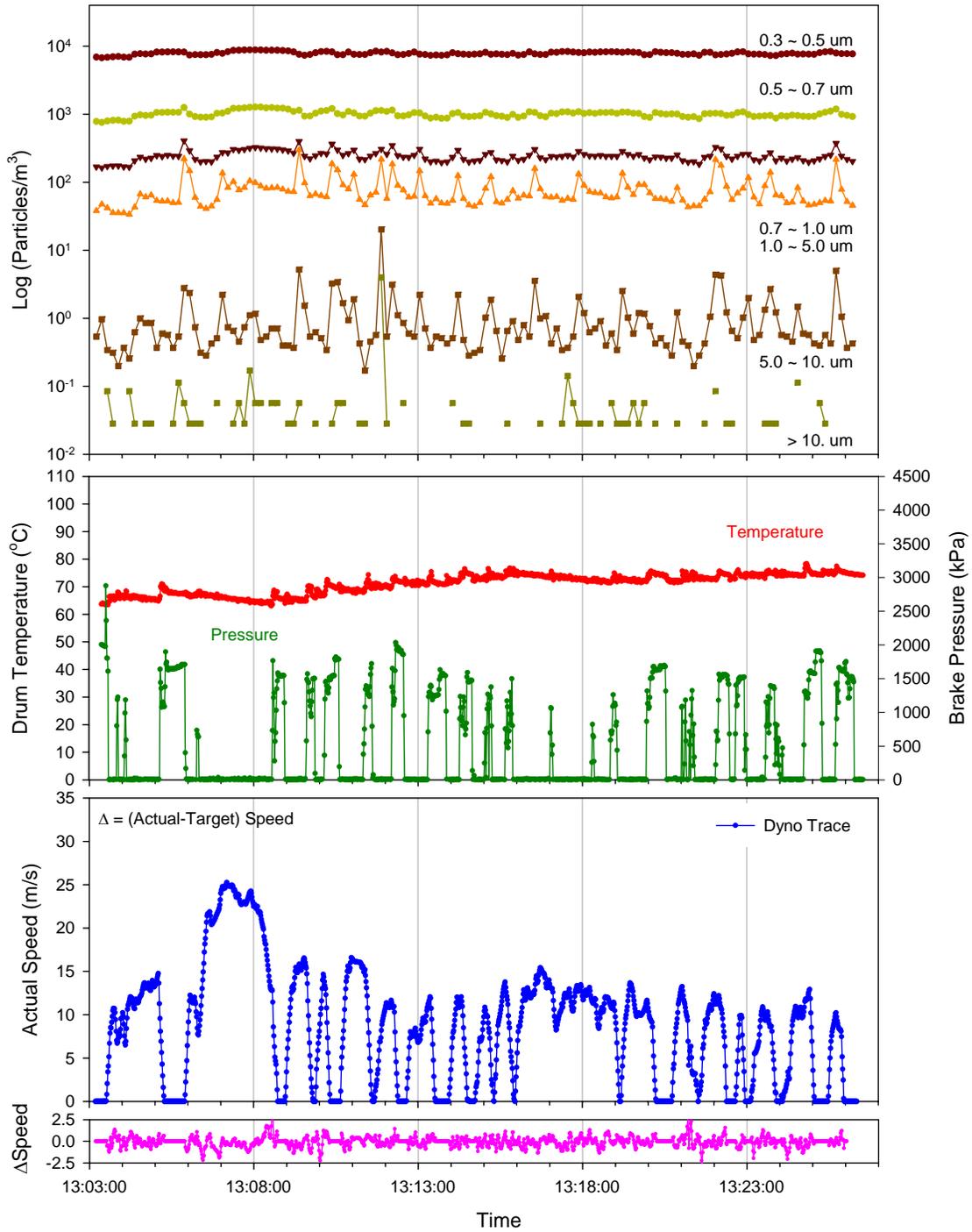
Dyno Day 3- Run 2



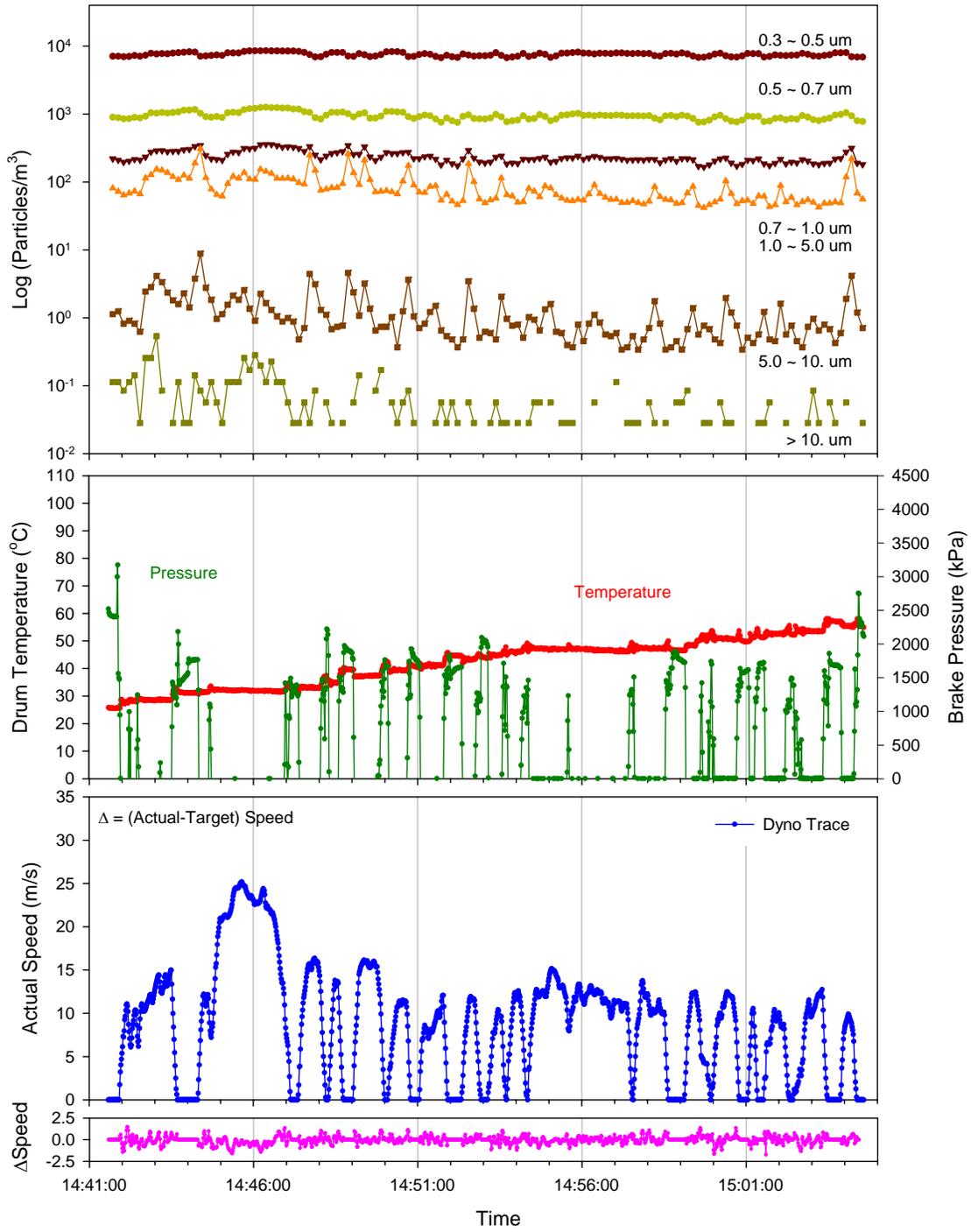
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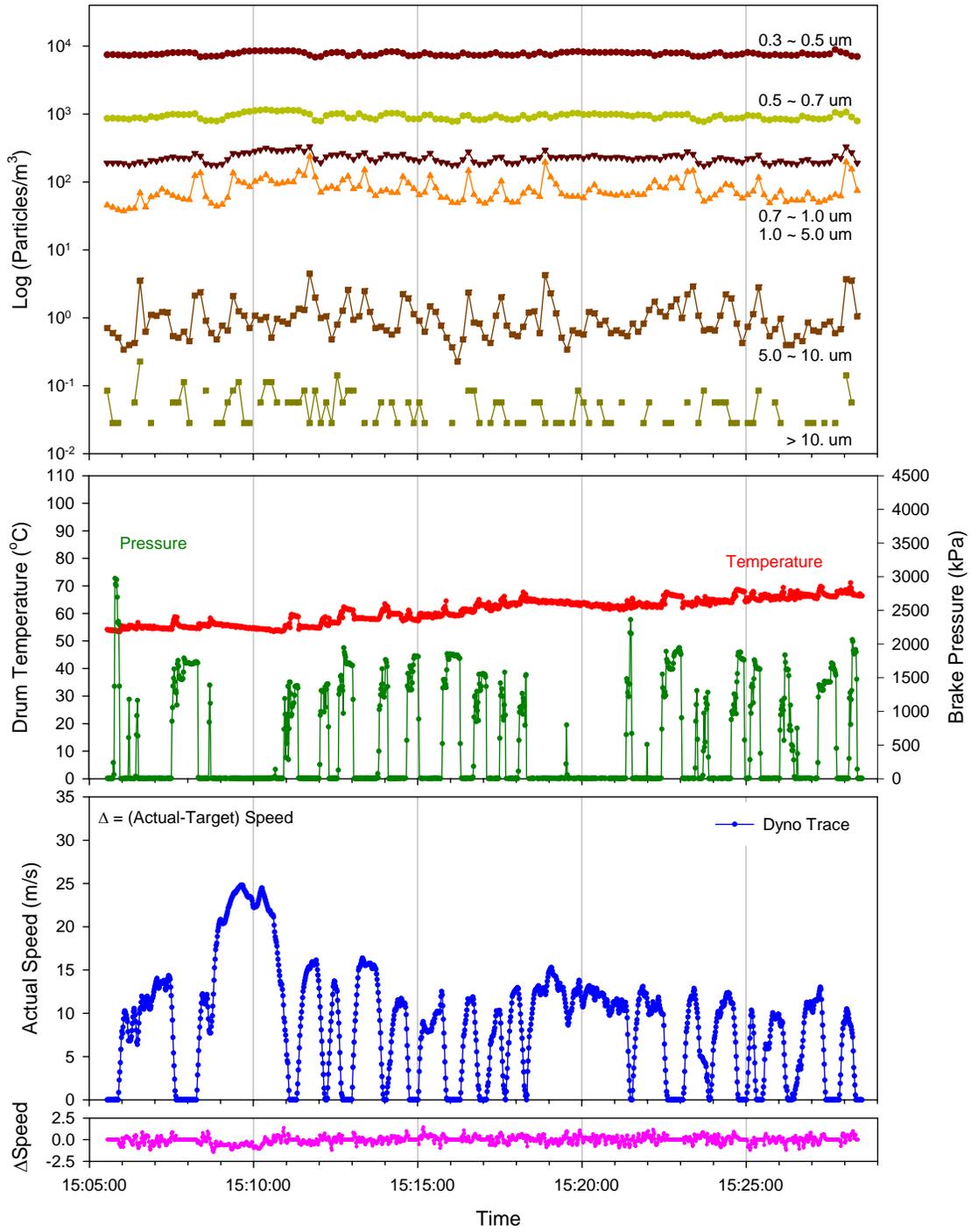
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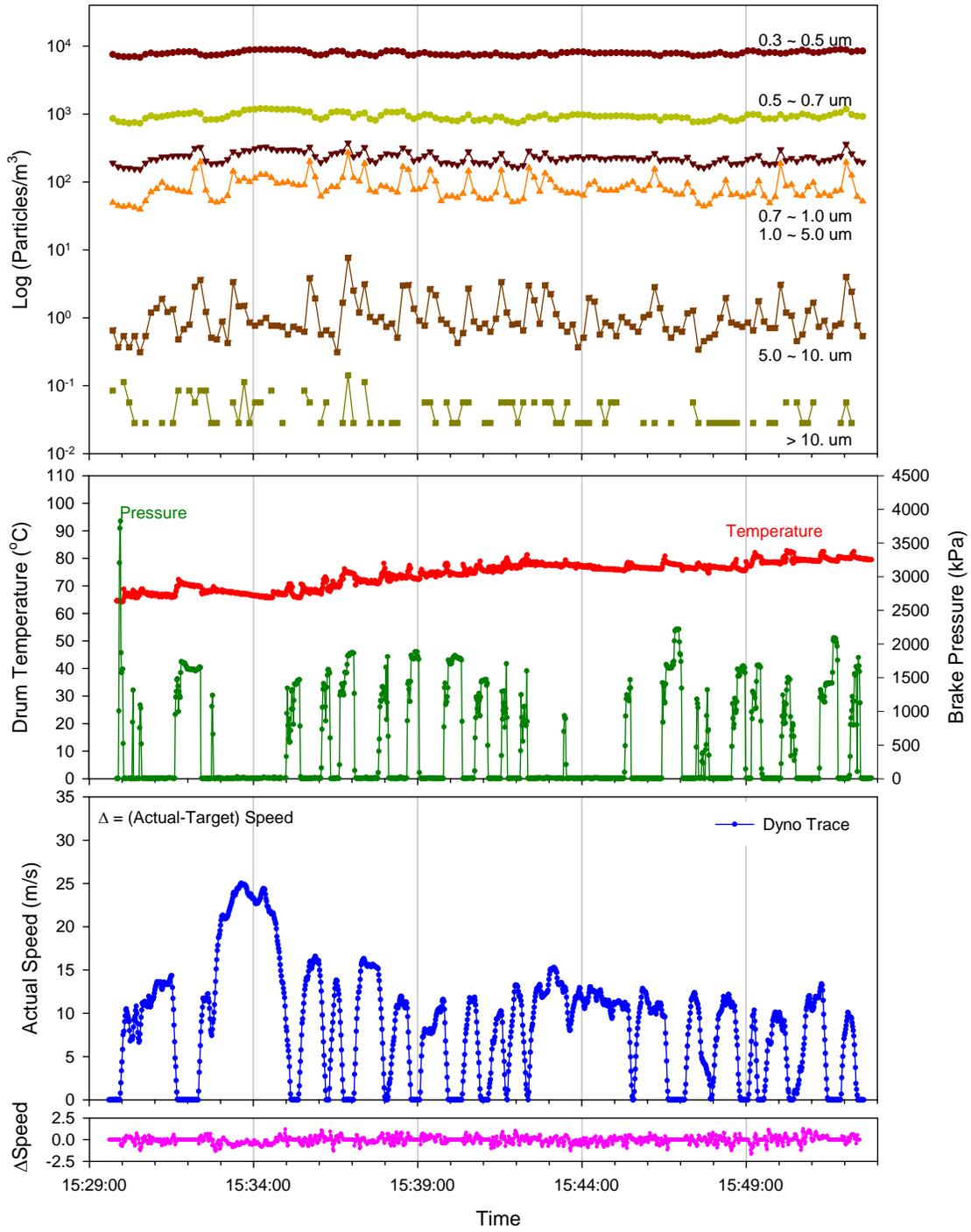
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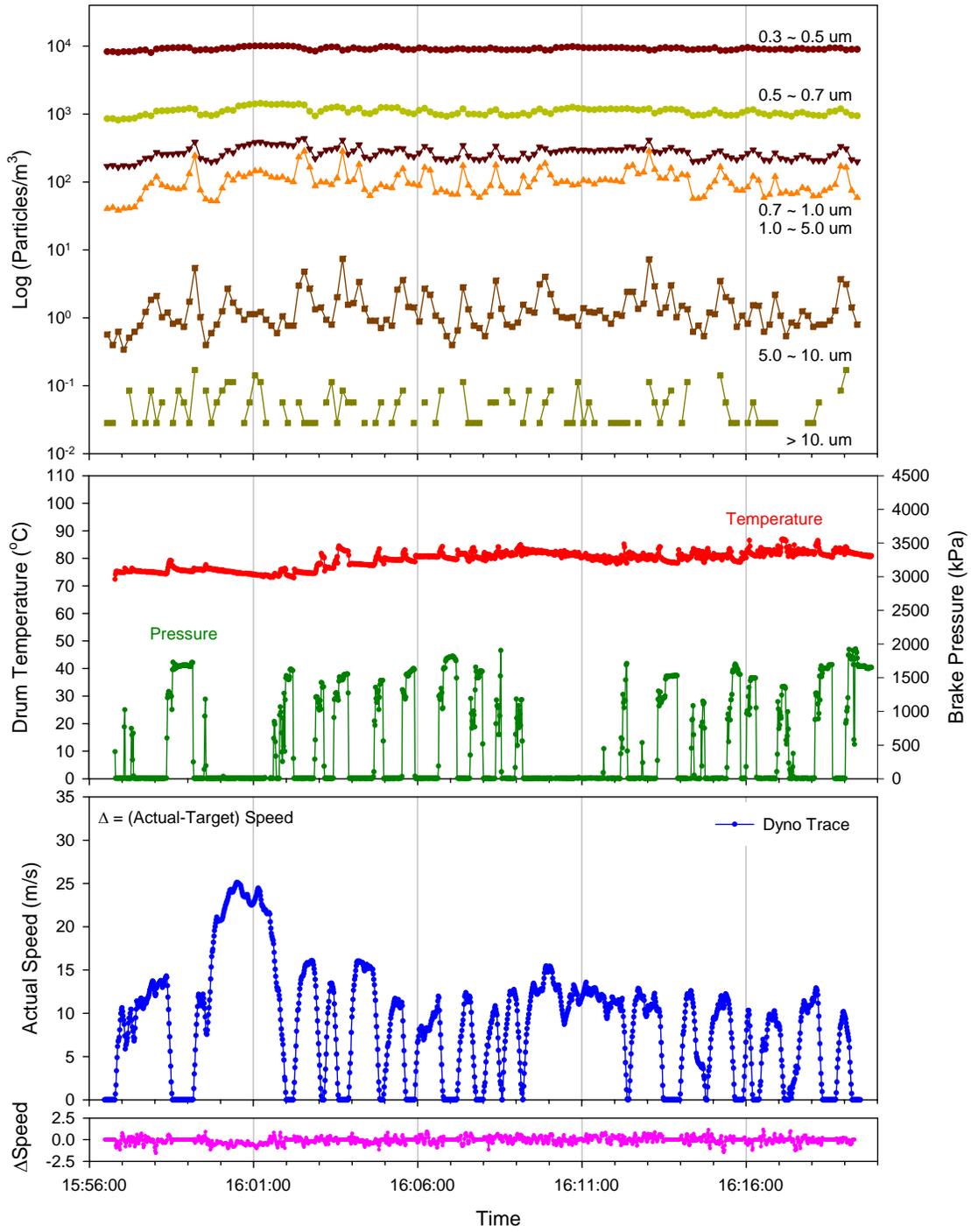
Dyno Day 3- Run 6



Dyno Day 3- Run 7



Dyno Day 3- Run 8



Appendix I: TEM Asbestos Fiber Counts for Dust and Air Samples Collected during Brake Emission Testing

Post-Dyno, Drum Dust CARB Cycle
 dust sample ID E0409026-006
 analyst JW
 date 3/22/2001
 R.Rear Brake Emission
1985 Chevy G20

dust mass g

funnel inner diameter mm
 filtered area mm²

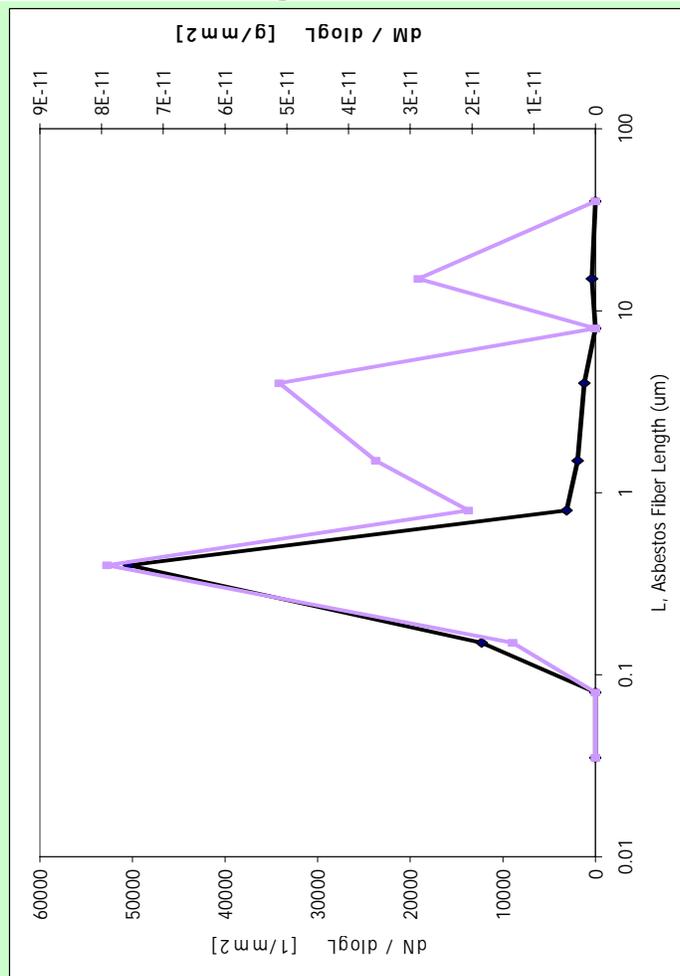
original water volume mL
 filtered subsample volume mL

Sensitivity (0.01 - 0.6um) %
 Sensitivity (0.6 - 60um) %

Chrysotile fibers counted 32
 other fib (not MgSi or < Lmin) 9

fib with CHRY SAED 27

Llow(um)	Lhigh(um)	Lmid(um)	# of CHRY area (mm ²)	mad1 58000 Lmin(um)	# of CHRY area (mm ²)	mad2 9700 Lmin(um)	N (1/mm ²)	dN/dlogL (1/mm ²)	M (g/mm ²)	dM/dlogL (g/mm ²)
0.01	0.06	0.035	0	0.00054065	0	0	0	0	0	0
0.06	0.1	0.08	0	0.00054065	0	0	0	0	0	0
0.1	0.2	0.15	2	0.00054065	0	0	3699.285113	12288.75915	4.034E-12	1.3401E-11
0.2	0.6	0.4	13	0.00054065	0	0	24045.35324	50396.73458	3.776E-11	7.91313E-11
0.6	1	0.8	2	0.00054065	4	0.0081473	690.6136966	3112.993415	4.571E-12	2.06022E-11
1	2	1.5	0	0.00054065	5	0.0081473	575.5114138	1911.807535	1.071E-11	3.55651E-11
2	6	4	1	0.00054065	4	0.0081473	575.5114138	1206.216257	2.443E-11	5.11993E-11
6	10	8	0	0.00054065	0	0.0081473	0	0	0	0
10	20	15	0	0.00054065	1	0.0081473	115.1022828	382.3615069	8.631E-12	2.86708E-11
20	60	40	0	0.00054065	0	0.0081473	0	0	0	0
>60			18		14					



Field Collected Dust

dust sample ID E0408015-8
 analyst JW
 date 12/13/2000
 Rear Brake Drum Dust
1996 Pontiac GM

dust mass 0.0056g

funnel inner diameter 16.25mm
 filtered area 207.3942025 mm2

original water volume 50mL
 filtered subsample volume 1mL

Sensitivity (0.01 - 2um) 0.000211182 %
 Sensitivity (2 - 60um) 5.29888E-05 %

Brake Shop

E0408015-8
 JW
 12/13/2000

1996 Pontiac GM

0.0056g

16.25mm
 207.3942025 mm2

50mL
 1mL

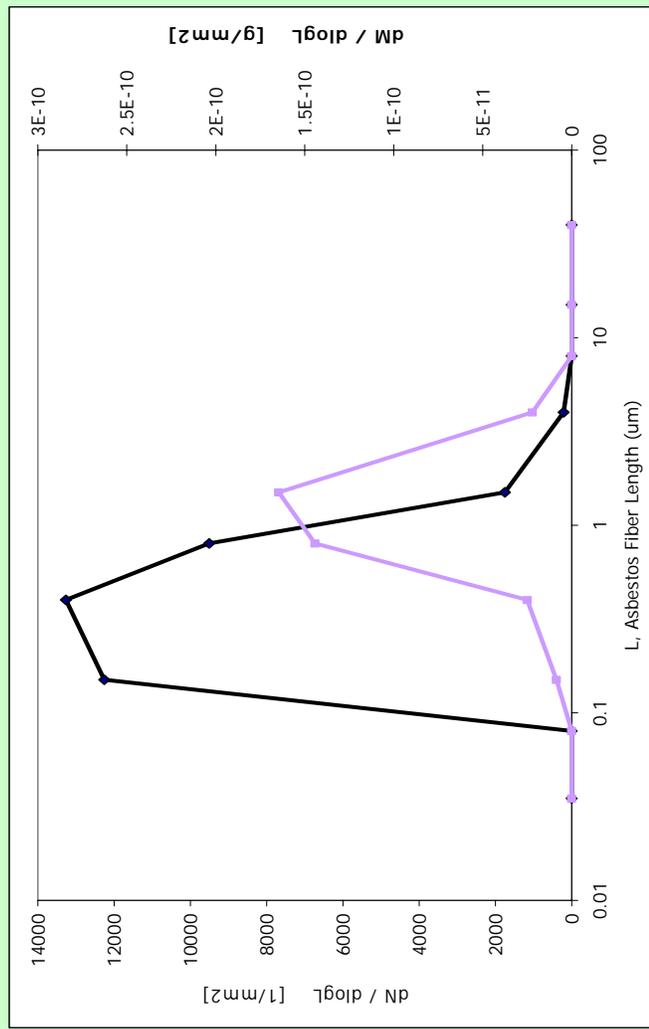
0.000211182 %
 5.29888E-05 %

Chrysotile fibers counted

other fib (not MgSi or < Lmin) 29 5

fib with CHRY SAED 15

Llow(um)	Lhigh(um)	Lmid(um)	mad1 1450x Lmin(um)	# of CHRY area (mm2)	mad2 18500x Lmin(um)	# of CHRY area (mm2)	N (1/mm2)	dN/dlogL (1/mm2)	M (g/mm2)	dM/dlogL (g/mm2)
0.01	0.06	0.035	0	0	0	0.0018966	0	0	0	0
0.06	0.1	0.08	0	0	0	0.0018966	0	0	0	0
0.1	0.2	0.15	0	0	7	0.0018966	3690.815143	12260.62252	2.585E-12	8.58729E-12
0.2	0.6	0.4	0	0	12	0.0018966	6327.117674	13261.01407	1.194E-11	2.50271E-11
0.6	1	0.8	0	0	4	0.0018966	2109.037225	9506.644631	3.201E-11	1.44277E-10
1	2	1.5	0	0	1	0.0018966	527.2593061	1751.517502	4.956E-11	1.64625E-10
2	6	4	0.04849488	1	0.0018966	99.22312264	207.9620676	0	1.051E-11	2.20273E-11
6	10	8	0.04849488	0	0.0018966	0	0	0	0	0
10	20	15	0.04849488	0	0.0018966	0	0	0	0	0
20	60	40	0.04849488	0	0.0018966	0	0	0	0	0
						4	25			

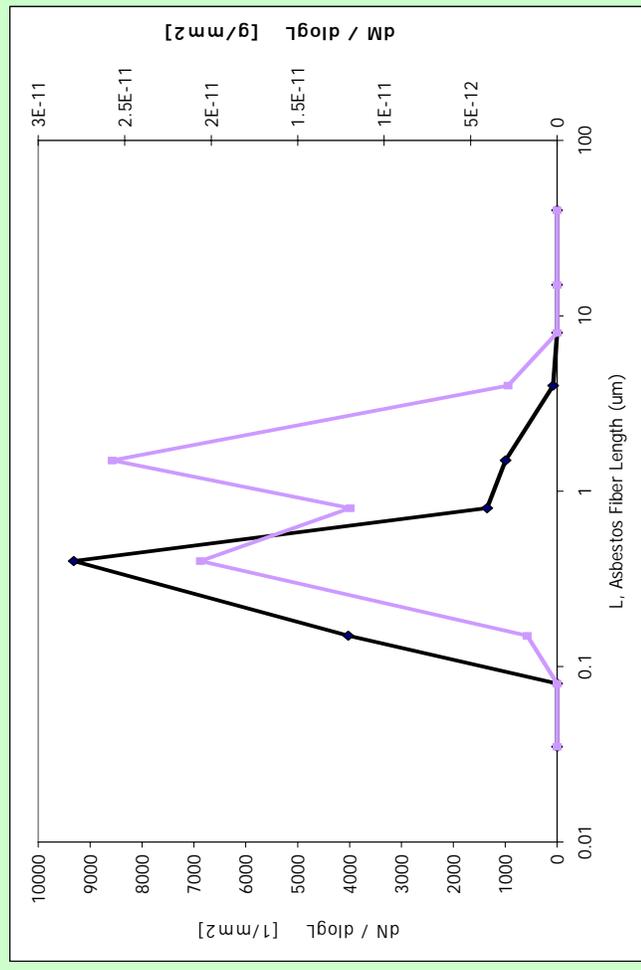


Field Collected Dust **Brake Shop**
 dust sample ID: E0409020-10
 analyst: JW
 date: 10/17/2001
Rear Brake Drum Dust **1998 Pontiac Sunfire**
 dust mass: 0.0056g
 funnel inner diameter: 16.25mm
 filtered area: 207.3942025 mm²
 original water volume: 50mL
 filtered subsample volume: 1mL
 Sensitivity (0.01 - 0.6um): 0.0001618 %
 Sensitivity (0.6 - 60um): 9.99212E-05 %

Chrysotile fibers counted **31**
 other fib. (not MgSi or < Lmin) 14

fib with CHRY SAED 38

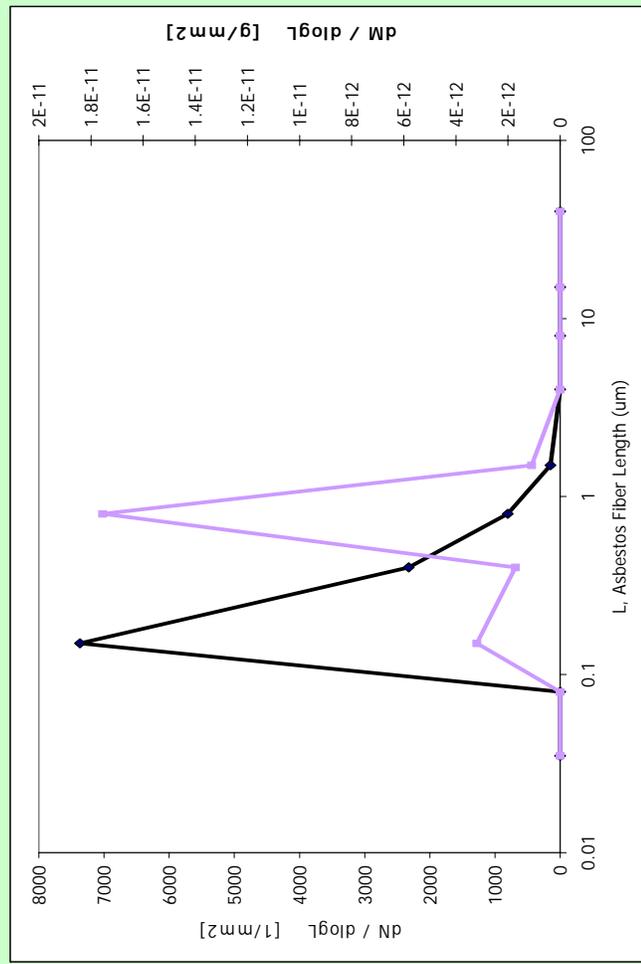
Low(um)	Lhigh(um)	Lmid(um)	# of CHRY	area (mm ²)	Lmin(um)	mag2	# of CHRY	area (mm ²)	N (1/mm ²)	dN/dlogL (1/mm ²)	M (g/mm ²)	dM/dlogL (g/mm ²)
0.01	0.06	0.035	0	0.0024755	0.01	58000x	0	0.0024755	0	0	0	0
0.06	0.1	0.08	0	0.0024755	0.01	58000x	0	0.0024755	0	0	0	0
0.1	0.2	0.15	3	0.0024755	0.01	58000x	1211	899887	4025.844284	0	5.194E-13	1.72544E-12
0.2	0.6	0.4	0	0.0024755	0.01	58000x	4443	63292	9313.424788	0	9.838E-12	2.06196E-11
0.6	1	0.8	8	0.02424744	0.01	58000x	299	3687959	1349.427465	0	2.654E-12	1.19613E-11
1	2	1.5	6	0.02424744	0.01	58000x	2	0.0024755	994.4816137	0	7.742E-12	2.57187E-11
2	6	4	1	0.02424744	0.01	58000x	37	42109948	78.43100493	0	1.354E-12	2.83732E-12
6	10	8	0	0.02424744	0.01	58000x	0	0.0024755	0	0	0	0
10	20	15	0	0.02424744	0.01	58000x	0	0.0024755	0	0	0	0
20	60	40	0	0.02424744	0.01	58000x	0	0.0024755	0	0	0	0
>60												



Field Collected Dust
 dust sample ID: E0409015-4
 analyst: JW
 date: 3/27/2001
 Rear Brake Shoe
1995 VW Jetta
 dust mass: 0.0056 g
 funnel inner diameter: 1.6, 25 mm
 filtered area: 207.3942025 mm²
 original water volume: 50 mL
 filtered subsample volume: 1 mL
 Sensitivity (0.01 - 0.6um): 0.000444379 %
 Sensitivity (0.6 - 60um): 0.000119015 %

Low(um)	Lhigh(um)	Lmid(um)	# of CHRY area (mm ²)	mag1 9700x Lmin(um) 0.6	# of CHRY area (mm ²)	mag2 58000x Lmin(um) 0.01	N (1/mm ²)	dM/dlogL (1/mm ²)	M (g/mm ²)	dM/dlogL (g/mm ²)
0.01	0.06	0.035	0	0	0	0	0.0009013	0	0	0
0.06	0.1	0.08	0	0	0	0	0.0009013	0	0	0
0.1	0.2	0.15	0	0	2	1	0.0009013	2218.967736	9.599E-13	3.18878E-12
0.2	0.6	0.4	0	0	0	0	0.0009013	1109.483868	8.177E-13	1.71384E-12
0.6	1	0.8	2	0.0215343	2	0	0.0009013	178.28797189	3.893E-12	1.75477E-11
1	2	1.5	1	0.0215343	0	0	0.0009013	44.57197974	3.278E-13	1.08889E-12
2	6	4	0	0.0215343	0	0	0.0009013	0	0	0
6	10	8	0	0.0215343	0	0	0.0009013	0	0	0
10	20	15	0	0.0215343	0	0	0.0009013	0	0	0
20	60	40	0	0.0215343	0	0	0.0009013	0	0	0
>60			3		5					

Chrysotile fibers counted
 other fib (not MgSi or < Lmin): 8
 1
 fib with CHRY SAED: 9



Dyno Run E3, PM2.5-10 CARB Cycle

air sample ID C:\G25_JW_E3
 analyst JW
 date 2/17/2001
 R.Rear Brake Emission **1985 Chvy G20**

funnel inner diameter **15.52** mm
 filtered area 189.179 mm²

Air Volume (V) **580.53** L

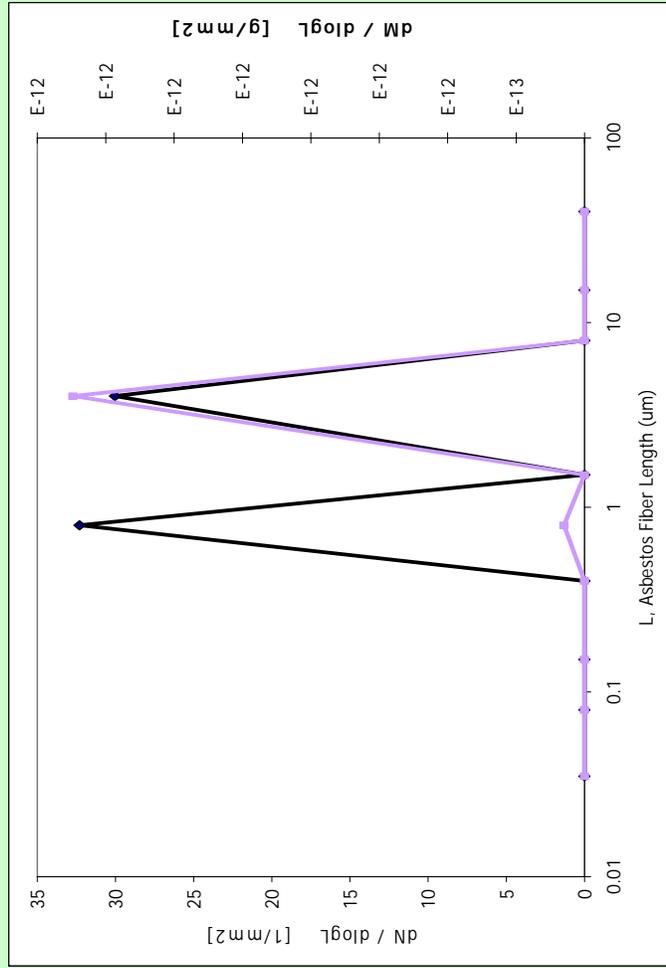
Sensitivity (0.01 - 0.4um)	0.2008 1/cc
Sensitivity (0.4 - 60um)	0.0023 1/cc

Chrysotile fibers counted 3
 other fib (not MgSi or < Lmin) 0

fib with CHRY SAED 3

Chry fib conc. in air 0.007004492 f/cc

Low(um) Lhigh(um) Lmid(um)	# of CHRY area (mm2)	mag1 9700x Lmin(um) 0.4	mag2 58000 Lmin(um) 0.01	N (1/mm2)	dN/dlogL (1/mm2)	M (g/mm2)	dM/dlogL (g/mm2)
0.01 0.06 0.035	0	0	0	0	0	0	0
0.06 0.1 0.08	0	0	0	0	0	0	0
0.1 0.2 0.15	0	0	0	0	0	0	0
0.2 0.6 0.4	0	0	0	0	0	0	0
0.6 1 0.8	1	0.13794648	0	7.164884814	32.29625962	3.336E-14	1.50385E-13
1 2 1.5	0	0.13794648	0	0	0	0	0
2 6 4	2	0.13794648	0	14.32976963	30.03381108	1.784E-12	3.73836E-12
6 10 8	0	0.13794648	0	0	0	0	0
10 20 15	0	0.13794648	0	0	0	0	0
20 60 40	0	0.13794648	0	0	0	0	0
>60	3	0	0	0	0	0	0



Dyno Run E3, PM2.5 **CARB Cycle**
 air sample ID CYS25_4P_E3
 analyst JW
 date 2/28/2001
 R. Rear Brake Emission **1985 Chevy G20**

filter deposit diameter mm
 deposit area (A_t) mm²
 Air Volume (V) liters

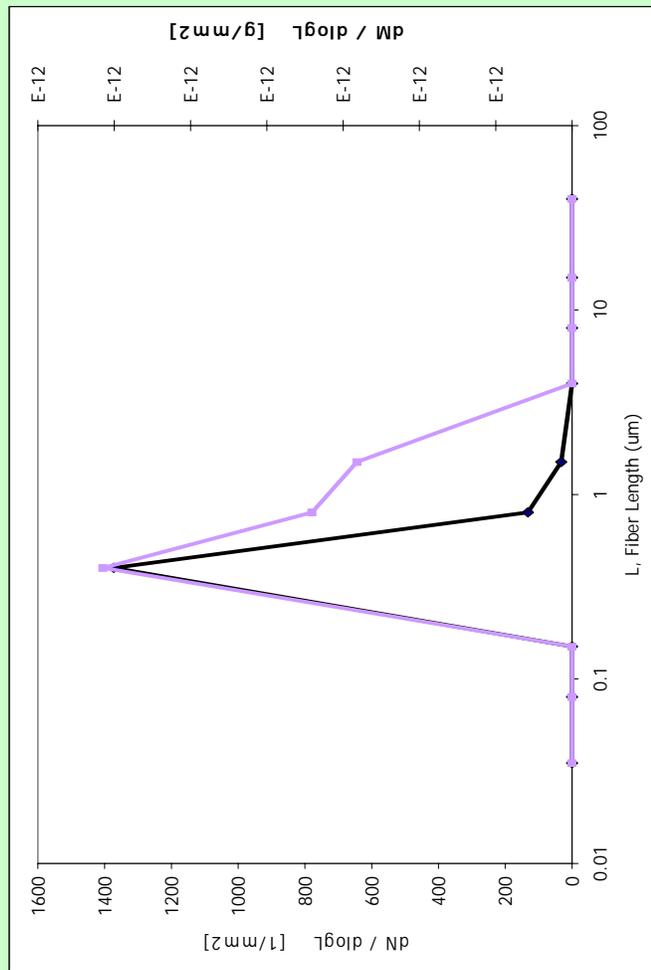
Sensitivity (0.01 - 0.6um) 1/cc
 Sensitivity (0.6 - 60um) 1/cc

Chrysotile fibers counted
 other fib (not MgSi or < Lmin) 18
 19

fib with CHRY SAED 0

Chry fib conc. in air 1.150205507 f/cc

Low(um) Lhigh(um) Lmid(um)	# of CHRY area (mm2)	mag1 9700x Lmin(um) 0.6	mag2 58000x Lmin(um) 0.01	N (1/mm2)	dN/dlogL (1/mm2)	M (g/mm2)	dM/dlogL (g/mm2)
0.01 0.06 0.035	0	0	0	0	0	0	0
0.06 0.1 0.08	0	0	0	0	0	0	0
0.1 0.2 0.15	0	0	0	0	0	0	0
0.2 0.6 0.4	0	0	6	0.0091604	0	0	0
0.6 1 0.8	7	0.29824092	2	0.0091604	1372.796764	2.933E-12	6.14626E-12
1 2 1.5	3	0.29824092	0	0.0091604	131.9713752	7.56E-13	3.40766E-12
2 6 4	0	0.29824092	0	0.0091604	32.41945432	8.485E-13	2.81872E-12
6 10 8	0	0.29824092	0	0.0091604	0	0	0
10 20 15	0	0.29824092	0	0.0091604	0	0	0
20 60 40	0	0.29824092	0	0.0091604	0	0	0
>60	10	0	8	0	0	0	0



Dyno Run E9, PM2.5-10 Federal Cycle

air sample ID CYG25_W1_E9
 analyst JW
 date 9/6/2001
 R: Rear Brake Emission **1985 Chevy G20**

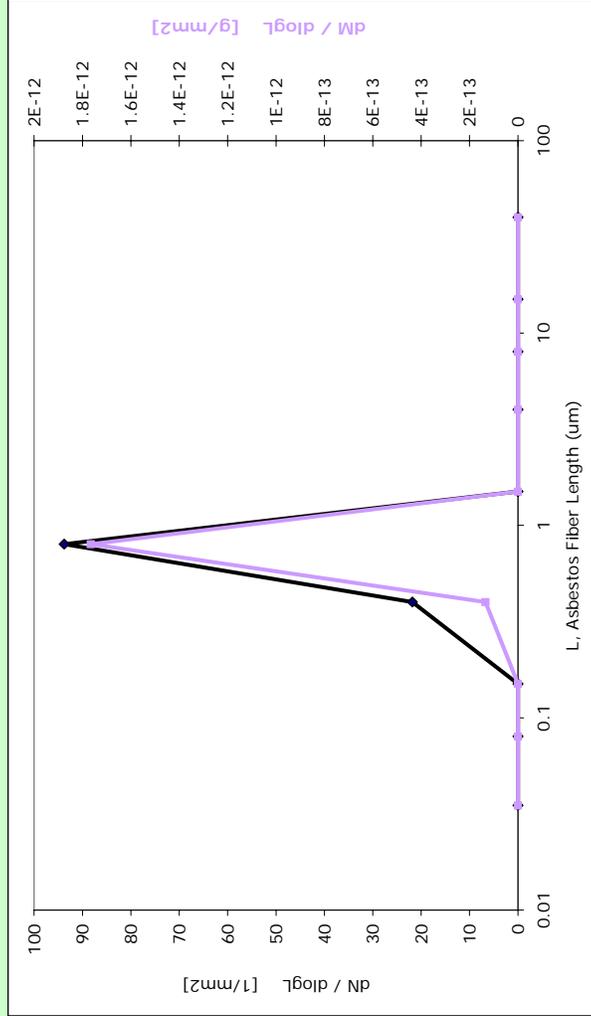
funnel inner diameter 15.52 mm
 filtered area 189.179 mm²
 Air Volume (V) 1120.58 L
 Sensitivity (0.01 -0.4um) 0.0406 f/cc
 Sensitivity (0.4 - 60um) 0.0018 f/cc

Chrysotile fibers counted
 other fib (not MgSi or < Lmin) 3
 0

fib with CHRY SAED 3

Chry fib conc: in air 0.005268889 f/cc

Flow(um)	Lhigh(um)	Lmid(um)	# of CHRY area (mm2)	mag1 9700x Lmin(um) 0.4	# of CHRY area (mm2)	mag2 58000 Lmin(um) 0.1	N (1/mm2)	dN/dlogL (1/mm2)	M (g/mm2)	dM/dlogL (g/mm2)
0.01	0.06	0.035	0	0	0	0	0	0	0	0
0.06	0.1	0.08	0	0	0	0	0	0	0	0
0.1	0.2	0.15	0	0	0	0	0	0	0	0
0.2	0.6	0.4	1	0.09196432	0	0.0041599	10.4032086	21.80411897	6.401E-14	1.3415E-13
0.6	1	0.8	2	0.09196432	0	0.0041599	20.8064172	93.78649749	3.917E-13	1.76562E-12
1	2	1.5	0	0.09196432	0	0.0041599	0	0	0	0
2	6	4	0	0.09196432	0	0.0041599	0	0	0	0
6	10	8	0	0.09196432	0	0.0041599	0	0	0	0
10	20	15	0	0.09196432	0	0.0041599	0	0	0	0
20	60	40	0	0.09196432	0	0.0041599	0	0	0	0
>60			3				0	0	0	0



Dyno Run E9, PM2.5 Federal Cycle

air sample ID CYS25_2P_E9
 analyst JW
 date 8/8/2001
 R.Rear Drum Dust 1985 Chvy G20

filter deposit diameter 35 mm
 deposit area (At) 962.1128 mm²
 Air Volume (V) 1.12058 Liters

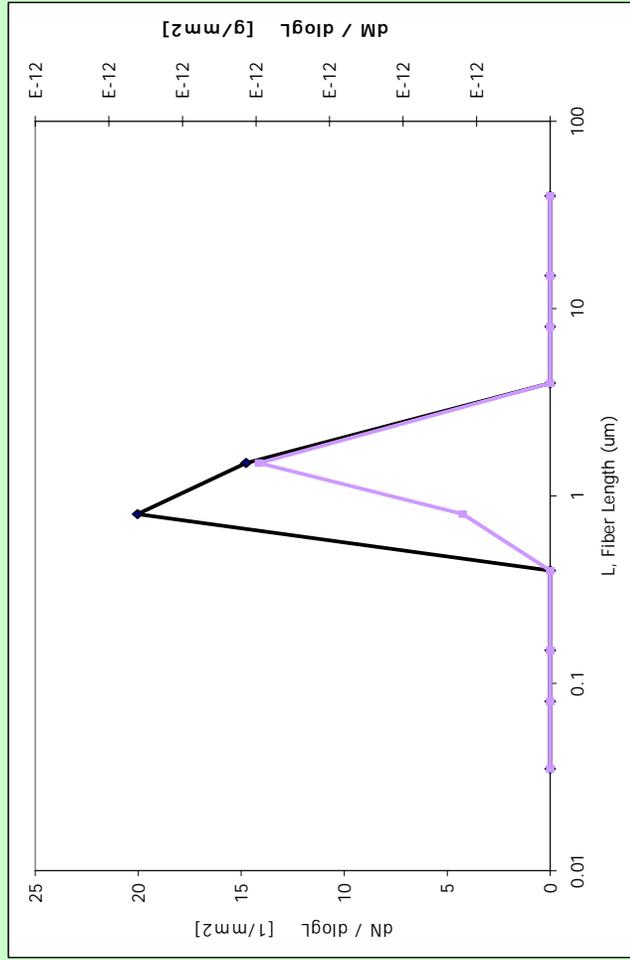
Sensitivity (0.01 - 0.6um) 0.2111 1/cc
 Sensitivity (0.6 - 6.0um) 0.0038 1/cc

Chrysoile fibers counted
 other fib (not MgSi or < Lmin) 2
 4

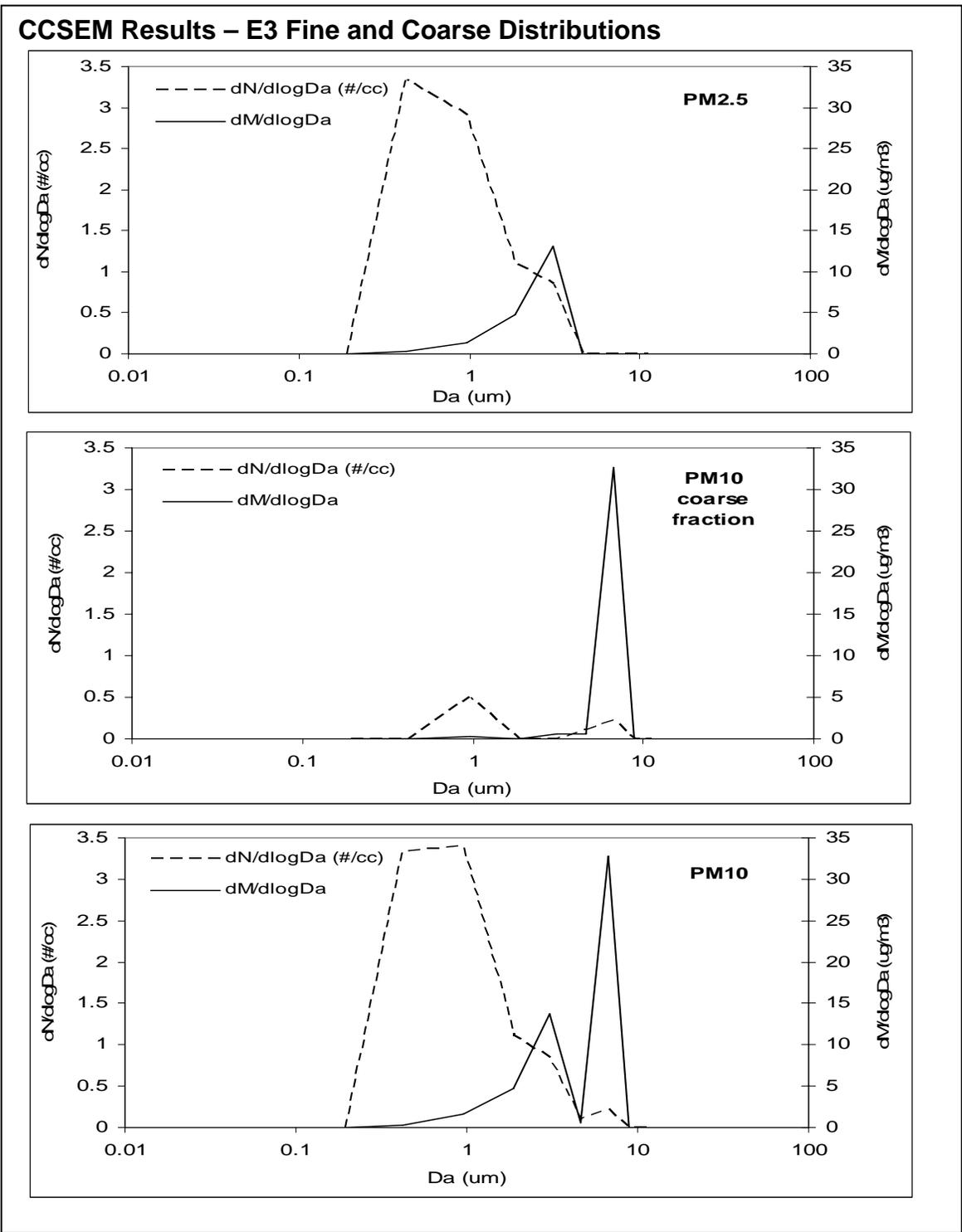
fib with CHRY SAED 1

Chry fib conc. in air 0.007632334 1/cc

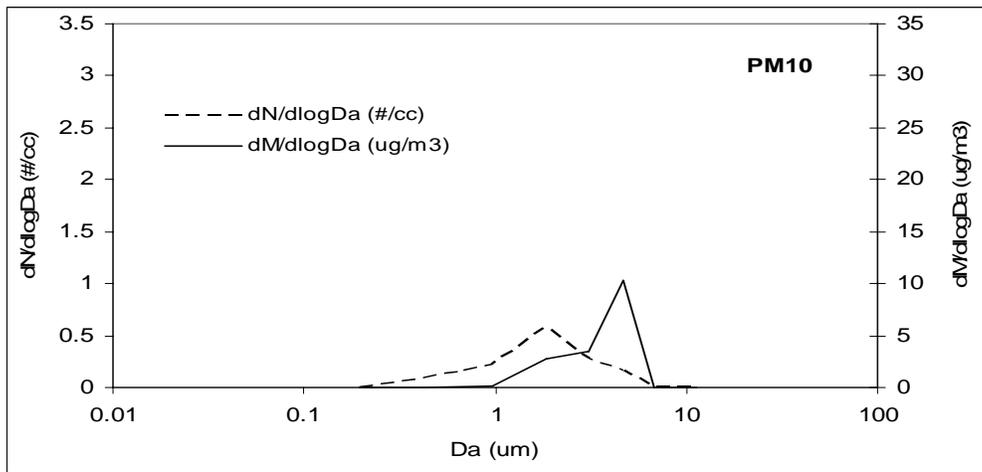
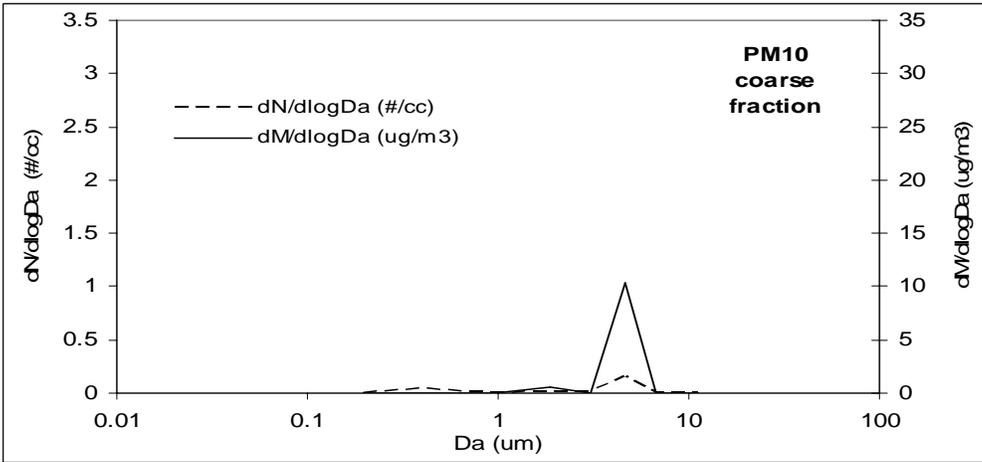
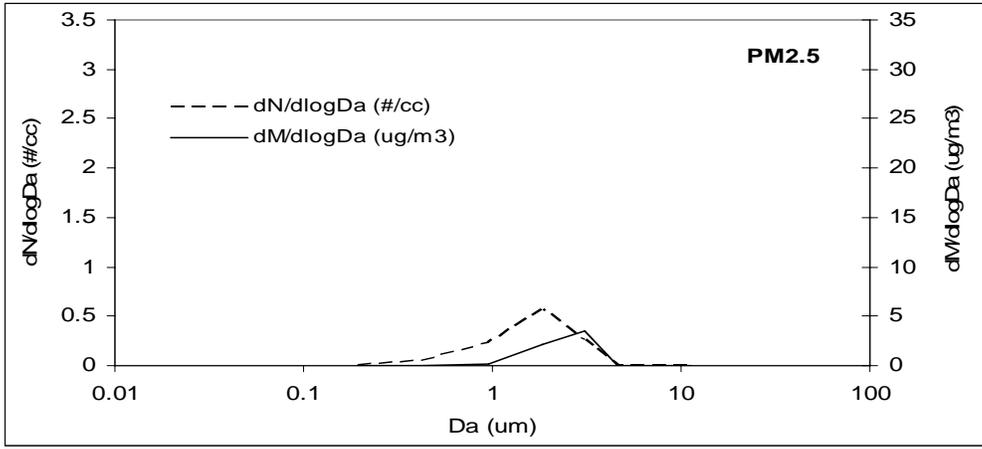
Low(um)	High(um)	Lmid(um)	# of CHRY area (mm ²)	Lmin(um)	# of CHRY area (mm ²)	Lmin(um)	N (1/mm ²)	dN/dlogL (1/mm ²)	M (g/mm ²)	dM/dlogL (g/mm ²)
0.01	0.06	0.035	0	0	0	0.0040669	0	0	0	0
0.06	0.1	0.08	0	0	0	0.0040669	0	0	0	0
0.1	0.2	0.15	0	0	0	0.0040669	0	0	0	0
0.2	0.6	0.4	0	0	0	0.0040669	0	0	0	0
0.6	1	0.8	1	0.2209192	0	0.0040669	4.444718634	20.03490505	2.635E-13	1.18771E-12
1	2	1.5	0	0.2209192	1	0.0040669	4.444718634	14.7650357	1.191E-12	3.95801E-12
2	6	4	0	0.2209192	0	0.0040669	0	0	0	0
6	10	8	0	0.2209192	0	0.0040669	0	0	0	0
10	20	15	0	0.2209192	0	0.0040669	0	0	0	0
20	60	40	0	0.2209192	0	0.0040669	0	0	0	0
>60			1		1					



Appendix J: Aerodynamic Particle Size Mass Distributions by CCSEM for Test Vehicle Brake Emission Air Samples



CCSEM Results – E9 Fine and Coarse Distributions



Appendix K. Preliminary Direct Evidence for the Conversion of Chrysotile Asbestos Fibers to a different Mineral Form by TEM SAED.

SEM/EDS Evidence for Heat Transformation of Chrysotile in BFM

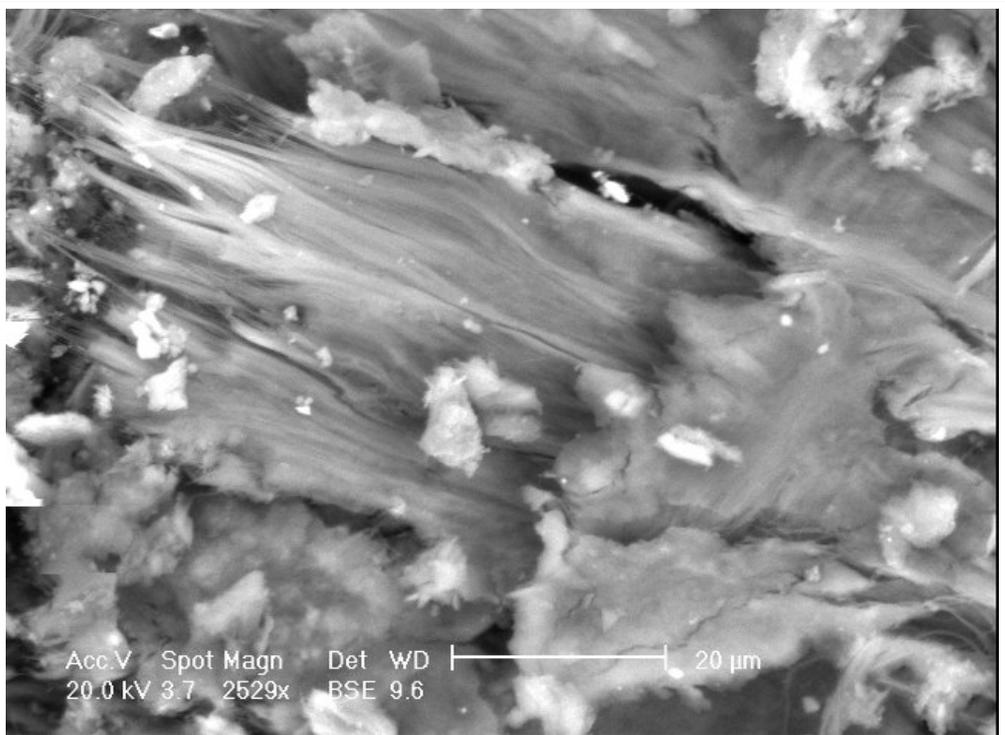
SEM/EDS was performed on brake shoe and brake dust samples to investigate the transformation of chrysotile asbestos at the braking surface.

Brake shoe samples were collected from two regions of the shoe: within the bulk of the shoe (Figure A) and at the surface (Figure B). Samples from within the bulk of the shoe consisted of 60% chrysotile asbestos bundles. These bundles were composed of magnesium and silicon, and were fibrous with rare smooth regions. Many of the smooth regions in Figure A are actually veils of fine, single fibrils when viewed with the higher-resolution, secondary electron detector at high magnification. However, some of these regions maintained their smooth appearance even when viewed at high resolution. These smooth regions appear to be 'melted' asbestos fibers, or more accurately, asbestos which has been transformed into non-fibrous, crystalline forsterite or an amorphous transitional state. The remainder of the non-surface bulk brake shoe material was composed of 15% iron oxides, 10% calcium oxides, 10% clay flakes (mostly aluminum and silicon), and 5% organic carbon.

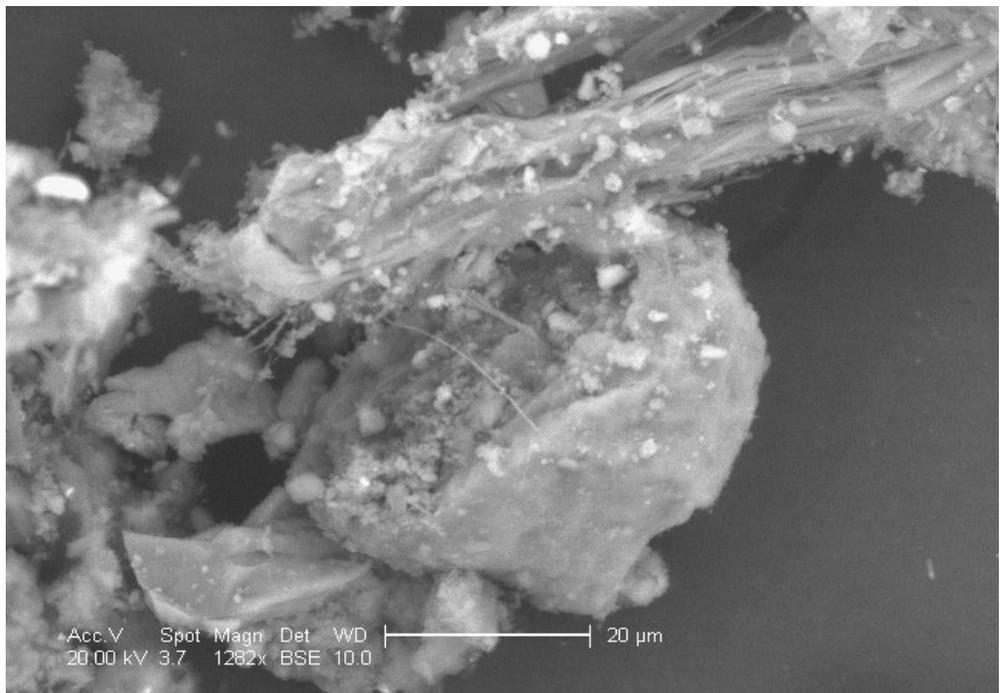
Samples from the shoe surface (Figure B) were different from those within the bulk of the shoe in that they exhibited a substantial amount of large, smooth, flattened flakes and round grains. The flakes and grains had no traces of fibrous morphology even at high magnifications, and were composed of magnesium, silicon, iron, and calcium. This composition implies that the flakes and grains are the product of chrysotile reacting with the iron and calcium oxides, induced by high temperatures and mechanical stress at the brake shoe-rotor interface. The composition at the shoe surface was typically 45% flakes/grains and 40% asbestos bundles.

Dust emissions collected from inside the brakes (Figure C) were almost entirely composed of these flakes and grains (> 80%). Only a small amount of fibrous chrysotile was found in the dust (<1%). The implication is that nearly all of asbestos emitted from the brake shoe was transformed by high temperatures into non-fibrous particles.

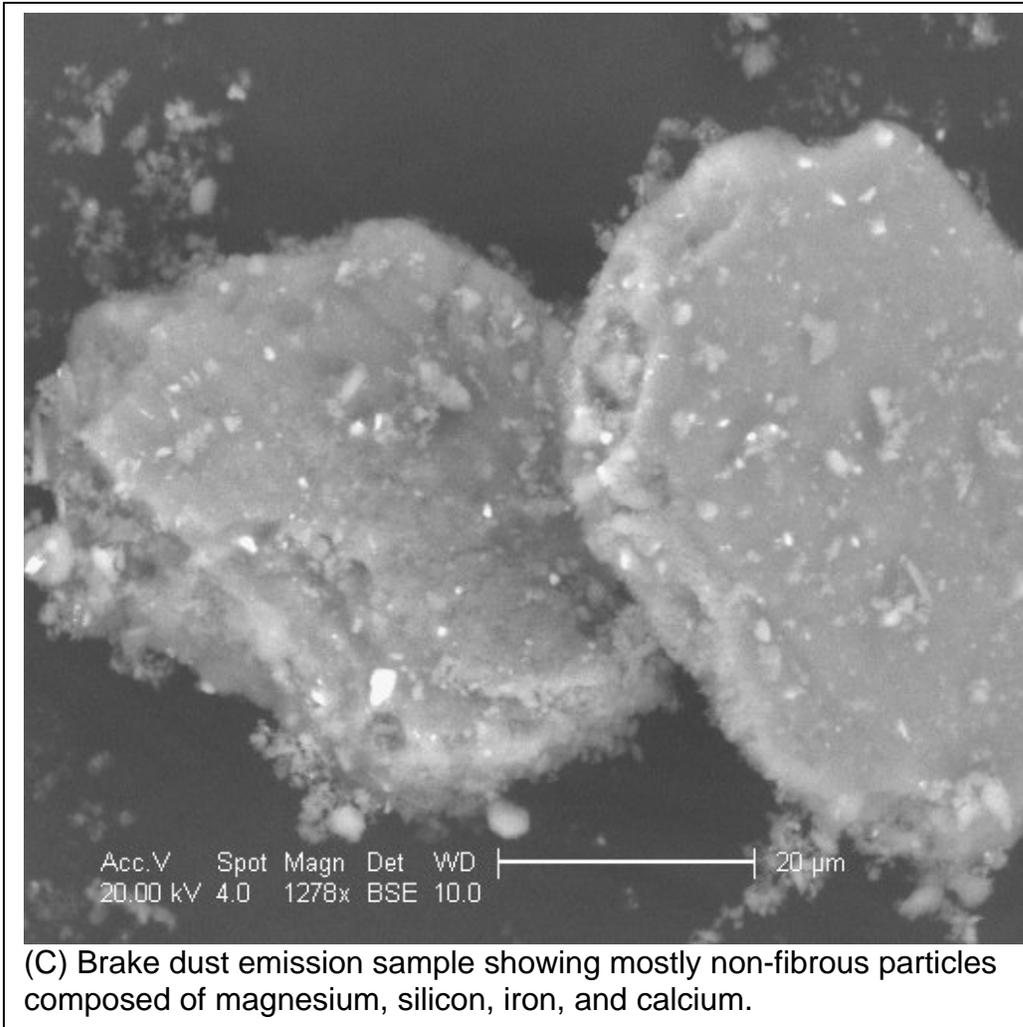
In summary, the brake shoe surface appears to be a transitional region between the mostly fibrous asbestos bulk of the brake shoes and the mostly non-fibrous brake emissions.



(A) Sample from within the bulk of a brake shoe showing mostly fibrous asbestos bundles.



(B) Shoe surface sample showing fibrous asbestos bundle and large, non-fibrous particles composed of magnesium, silicon, iron, and calcium.



TEM/SAED Evidence for Heat Transformation of Chrysotile in BFM

The TEM analyses of brake shoe surface material revealed magnesium silicate particles that had both fibrous and non-fibrous regions, suggesting a transition between chrysotile asbestos to a non-fibrous crystalline form. This transition is consistent with the theory that much of the asbestos in the brake was converted to non-fibrous forms at the shoe surface.

The particle shown in Figure 1 shows a fibrous morphology at the upper left, a plate-like morphology at the bottom, and a mixture of these morphologies elsewhere. The EDS revealed that the entirety of this particle, regardless of morphology, exhibited strong magnesium and silicon peaks and small amounts of iron, consistent with the composition of chrysotile. These EDS spectra were distinct from the EDS spectra of the other, minor (<5%), magnesium-silicate constituent of these brakes, which exhibits small magnesium peaks, as well as aluminum and potassium peaks.

Selected area electron diffraction (SAED) was performed at the four locations shown in Figure 1. Figure 2 shows the SAED pattern obtained from aiming the beam at location #1, which clearly exhibits chrysotile morphology. The SAED pattern, as well, shows the streaked layer lines characteristic of chrysotile.

Figure 3 shows the SAED pattern obtained from location #2, where the same fiber is partially encapsulated by a non-fibrous, possibly non-crystalline section of the particle. The chrysotile SAED pattern is weaker, and no other spots are visible. This is consistent with the initial, amorphous state of chrysotile when it is heated to the point where its structure begins to collapse.

Figure 4 shows the SAED pattern obtained from the middle of the particle at location #3. The complex spot pattern exhibits a mixture of radial symmetry, ordered spot patterns, and other, non-ordered spots. This pattern suggests a superposition of randomly-oriented chrysotile fibers and multiple crystalline structures, which is consistent with the morphology of location #3.

Figure 5 shows the SAED pattern obtained from the smooth, non-fibrous region at location #4. This pattern shows an ordered crystalline structure. Although definitive zone-axis patterns were not obtained, the crystalline structure and magnesium-silicate composition are both consistent with forsterite, the end product of the reaction of chrysotile with heat.

Together, these figures suggest that this particle was a short bundle of chrysotile asbestos that has been partially converted to a non-fibrous crystal. Both the morphology and SAED patterns from the middle of the particle suggest a transition between those of the fibrous upper left region and flake-like bottom of the particle.

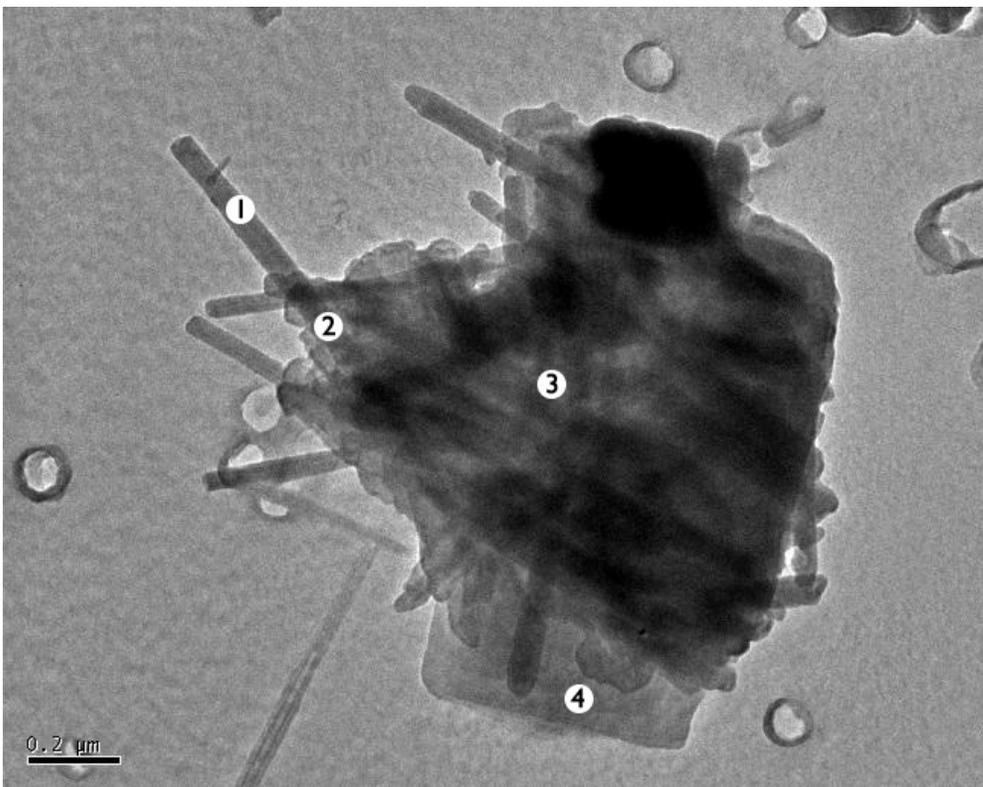


Figure 1. TEM micrograph of particle from brake shoe surface showing locations where SAED patterns were obtained.

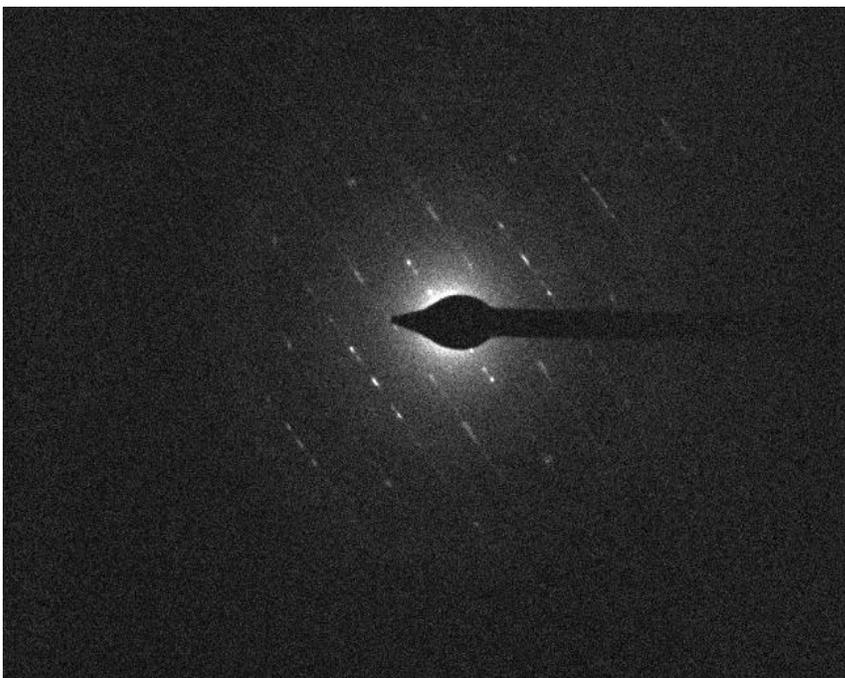


Figure 2. SAED pattern from location #1 on Figure 1.

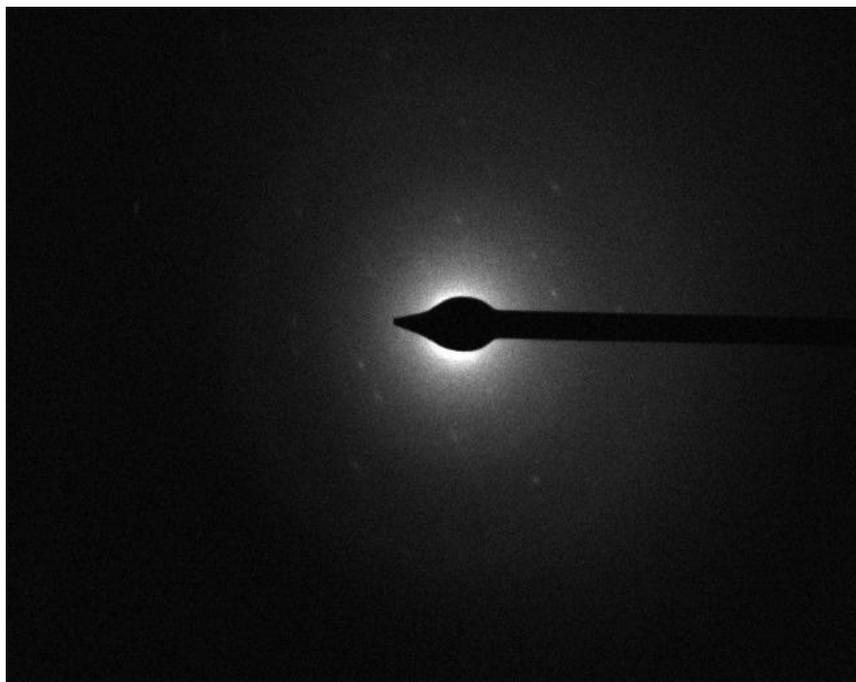


Figure 3. SAED pattern from location #2 on Figure 1.

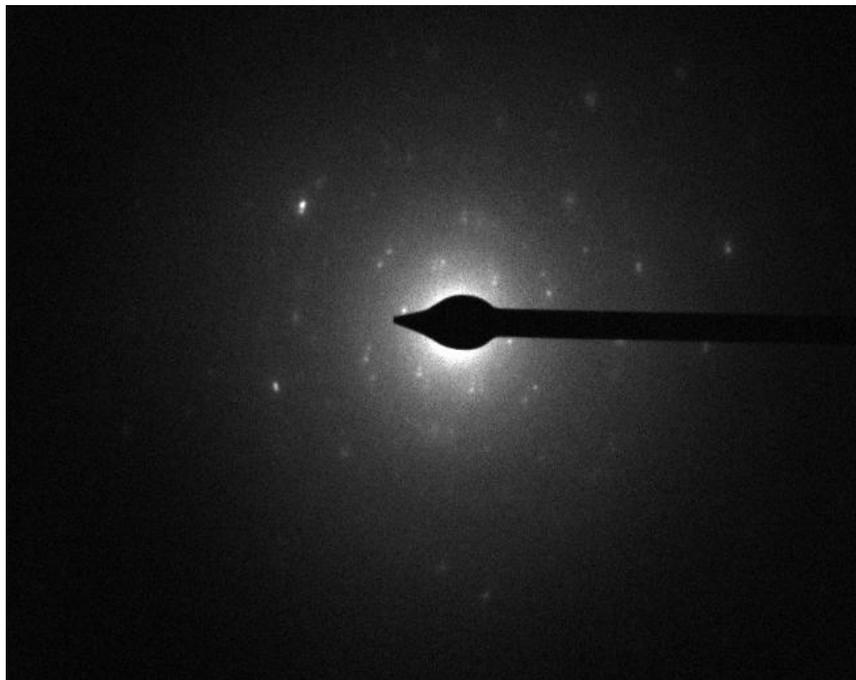


Figure 4. SAED pattern from location #3 on Figure 1

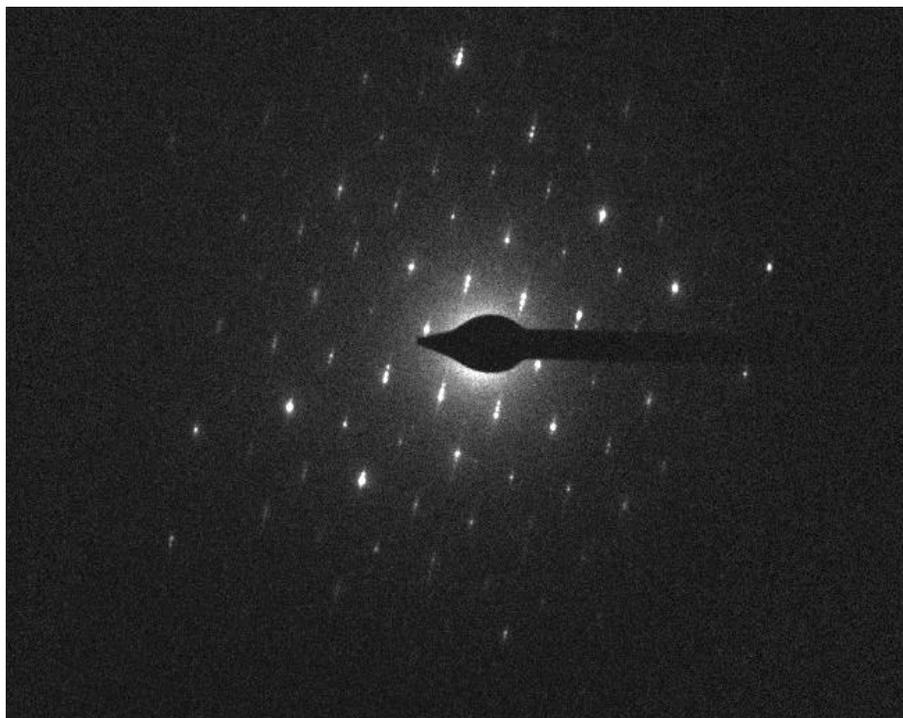


Figure 5. SAED pattern from location #4 on Figure 1